

# Groundwater Basics, California's Groundwater, and the CASGEM Program

Delta Stewardship Council  
West Sacramento, CA  
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Presented by:

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Division of Integrated Regional Water Management  
North Central Region Office



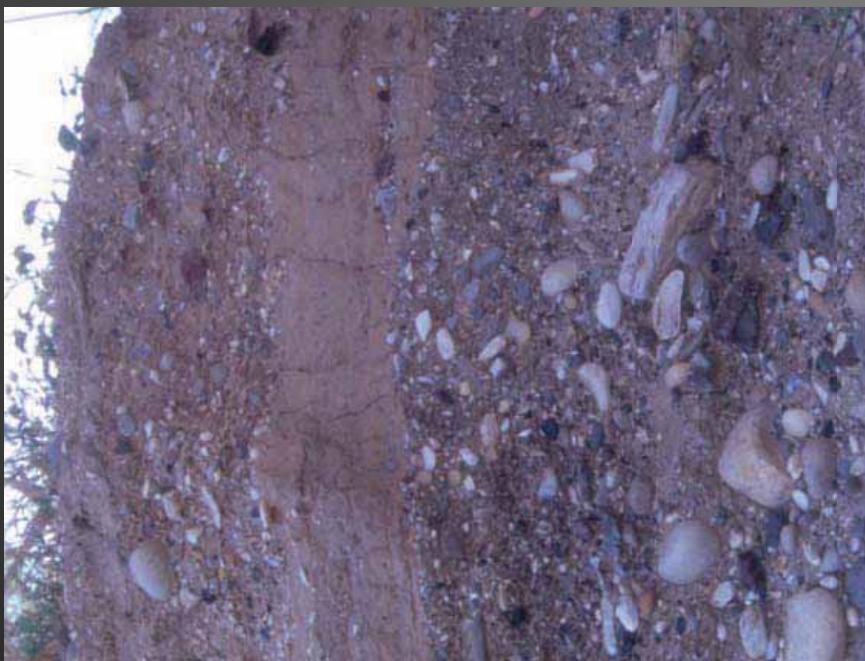
# Groundwater 101

- **Groundwater** is the water occurring beneath the earth's surface that completely fills the void space in rocks or sediment
- An **aquifer** is a body of rock or sediment that yields significant amounts of groundwater to wells or springs
- An **aquitard** is a body of rock or sediment that is capable of storing groundwater but does not yield it in significant or economic quantities
- A **groundwater basin** is defined as an alluvial aquifer with reasonably well-defined boundaries

# Examples of Aquifer Materials



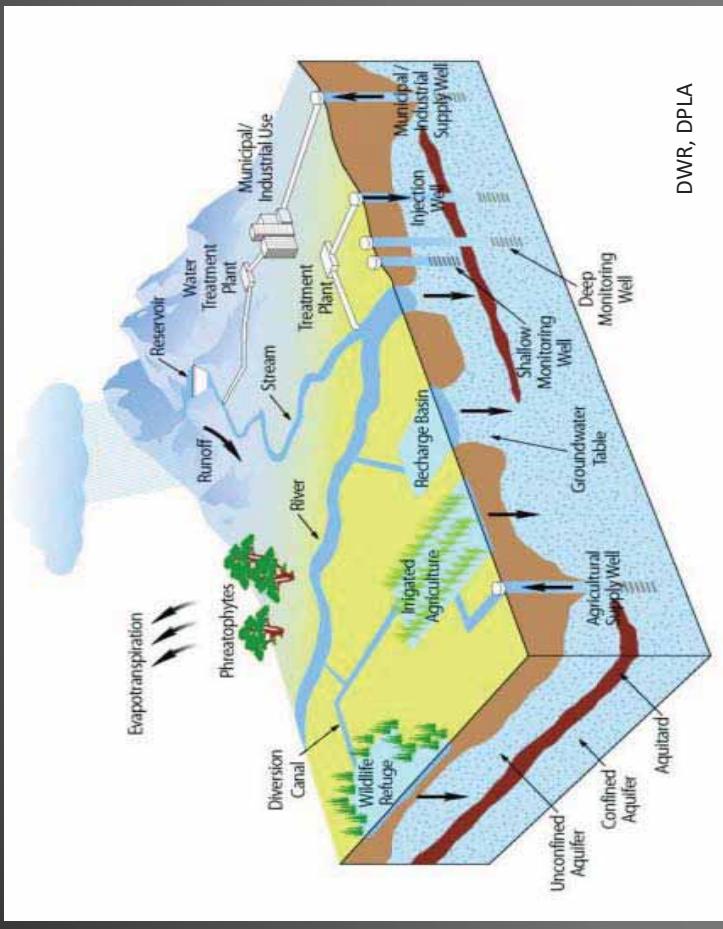
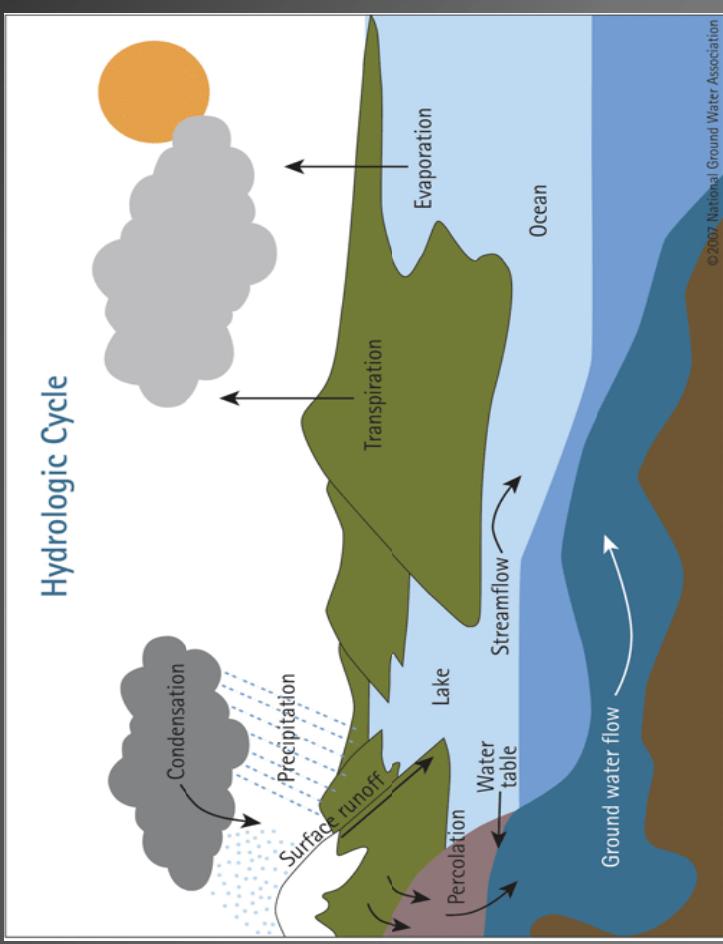
Fractured Rock Aquifer Material



Sand & Gravel Aquifer Material

# Hydrologic Cycle

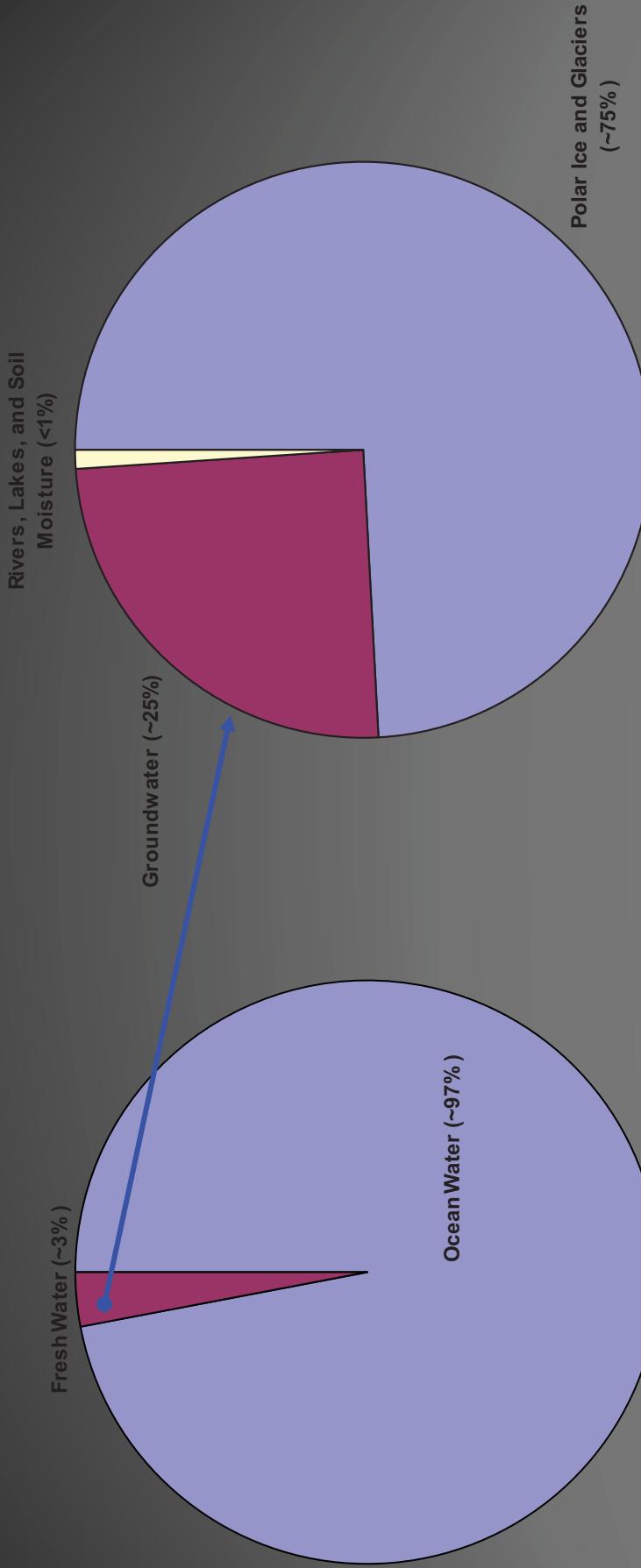
Groundwater is an important component of the hydrologic cycle



# Earth's Water Supply

Distribution of the World's Water

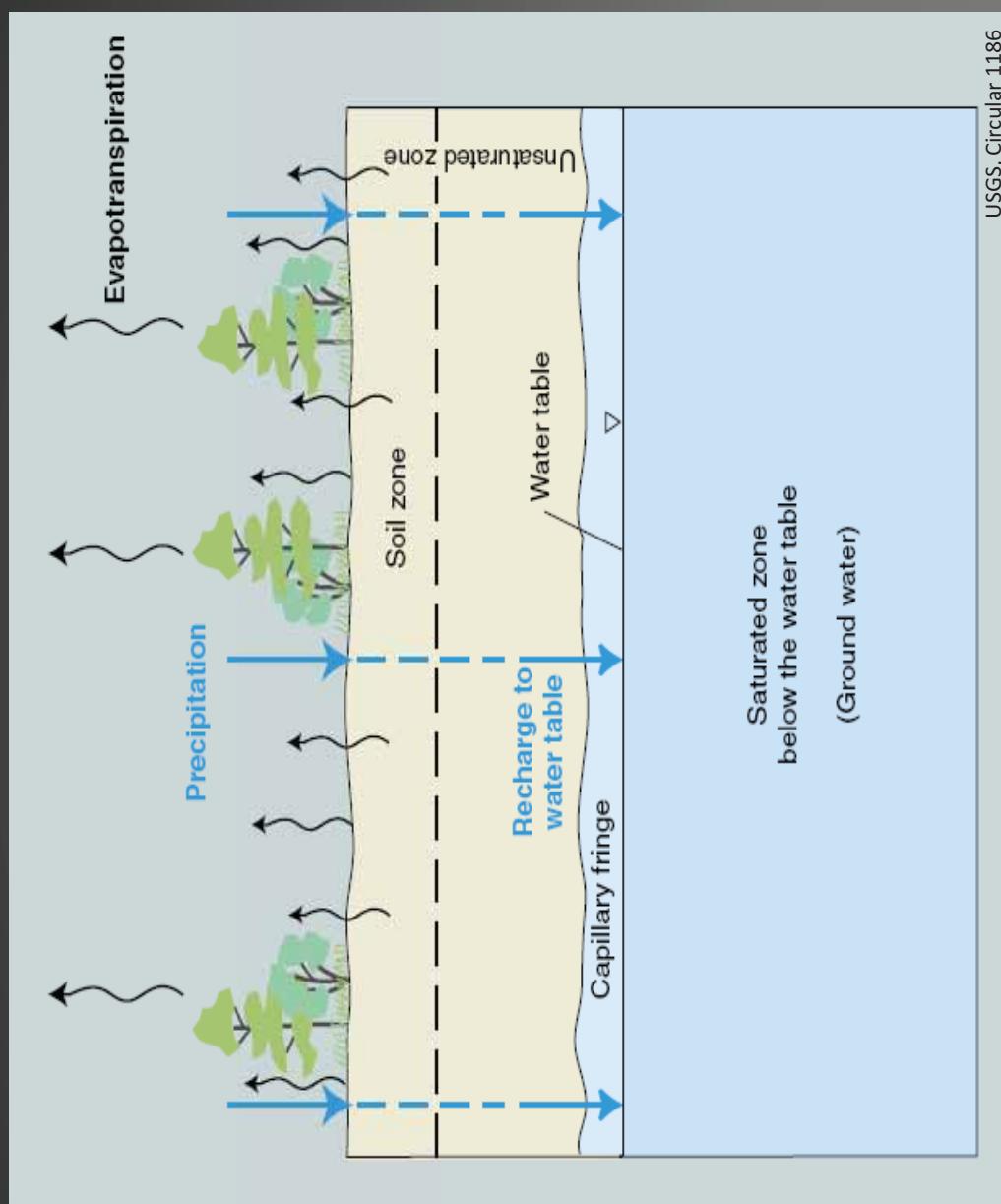
Distribution of the World's Fresh Water



Fetter 1988

Alley and others, 1999

# General Groundwater Concept



USGS, Circular 1186

# Occurrence of Groundwater

- Given that all rock has some open space (voids), groundwater can be found underlying nearly any location in the State
- Most of California's groundwater occurs in material deposited by rivers and streams, called alluvium

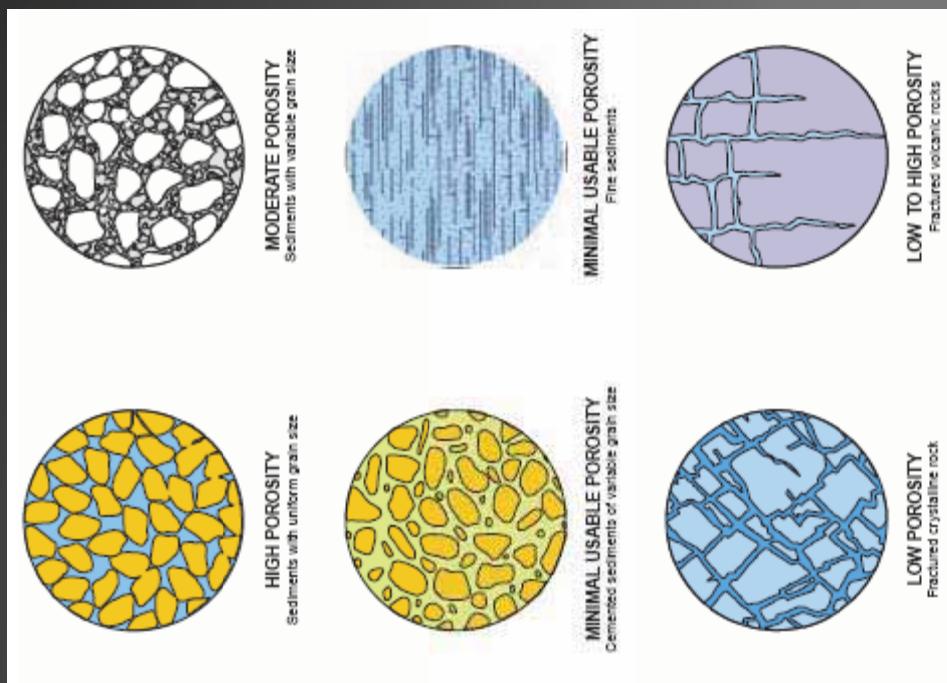


# What controls the occurrence and availability of groundwater?

- **Climate** (precipitation) controls the availability of water in an area
- **Geology** (rock type and structure) controls the capacity to store groundwater
  - **Porosity** is the ability of a soil or rock to contain water
  - **Permeability** is the ability of water to move through soil or rock

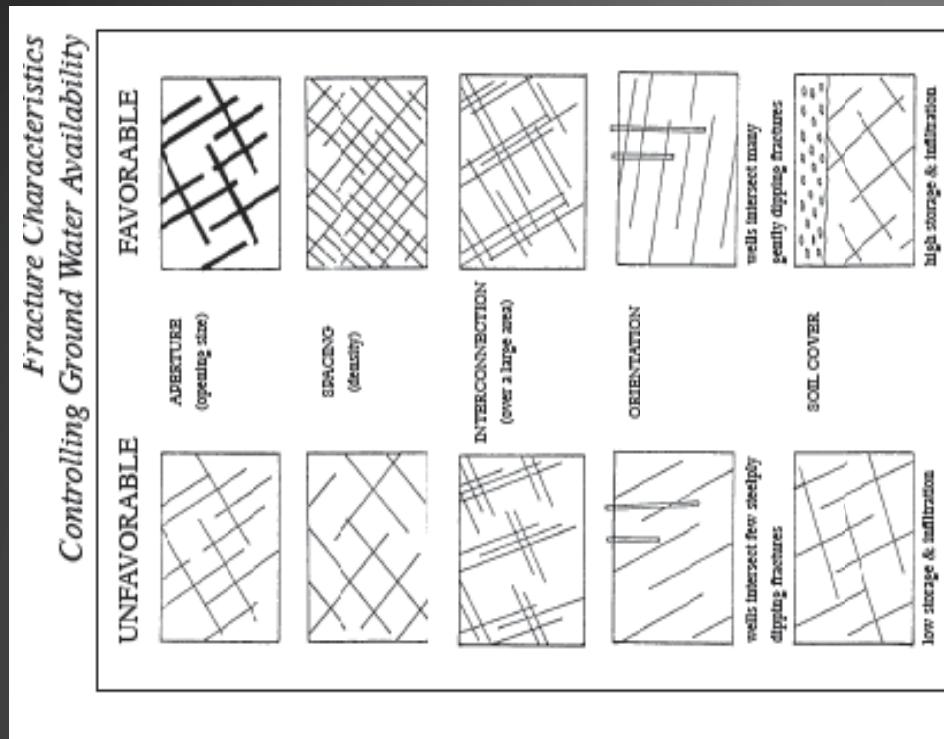
# Examples of Porosity in Rocks

- Sand & gravel, well sorted: 25-50%
- Sand & gravel, mixed: 20-35%
- Silt: 35-50%
- Clay: 33-60%
- Fractured crystalline rock: 1-10%
- Fractured volcanic rock: variable



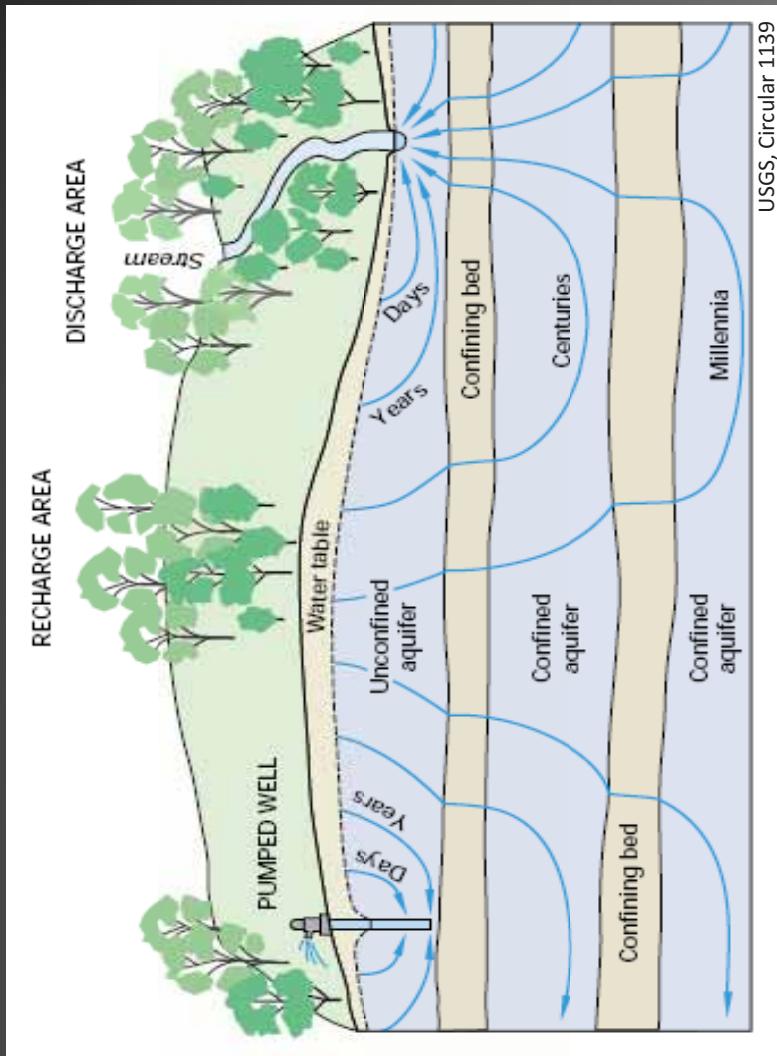
# Examples of Permeability in Rocks

- Sands & gravels are highly permeable
- Silts & clays have low permeability
- Fractured rock is variable, but typically low

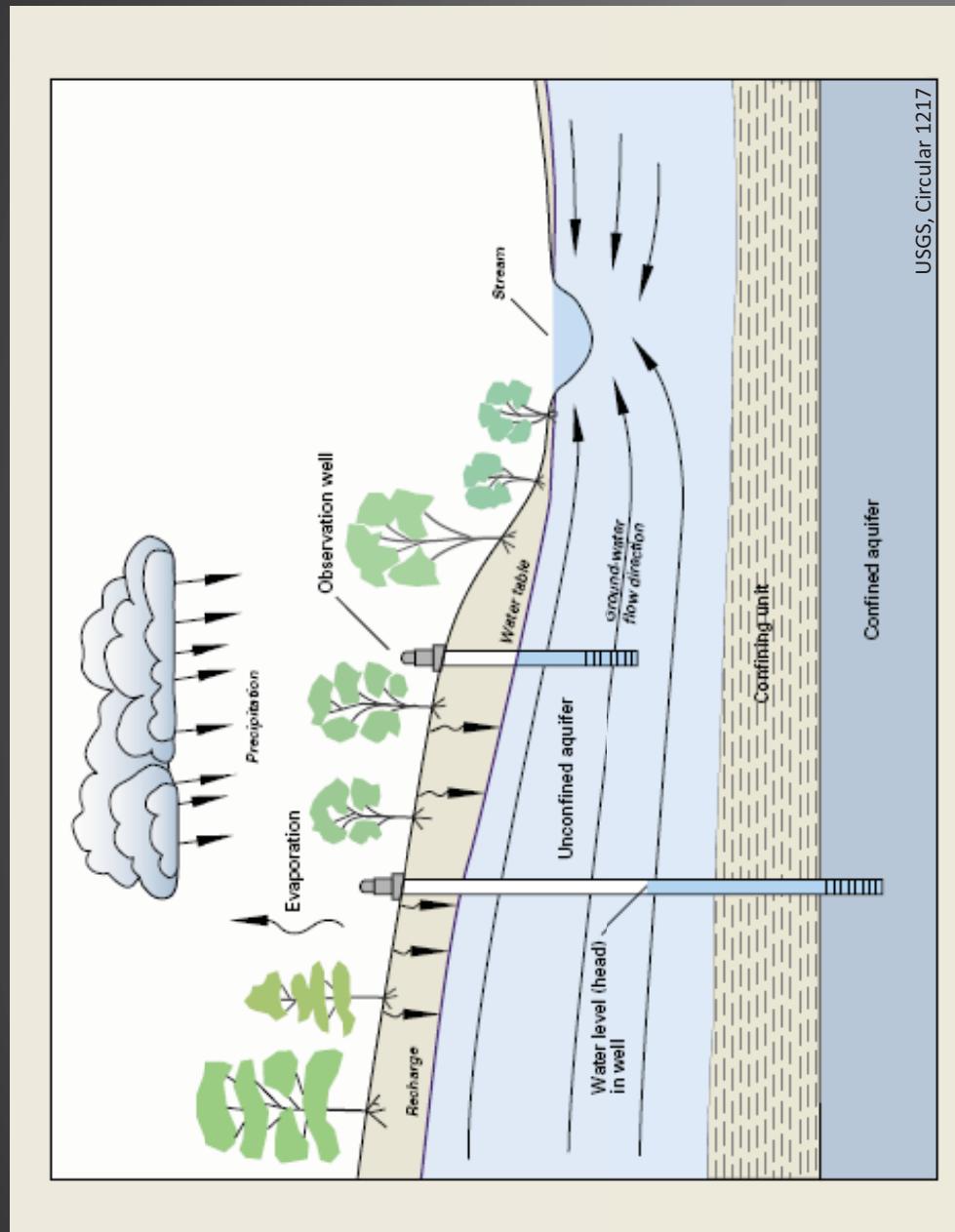


# Groundwater Flow Paths

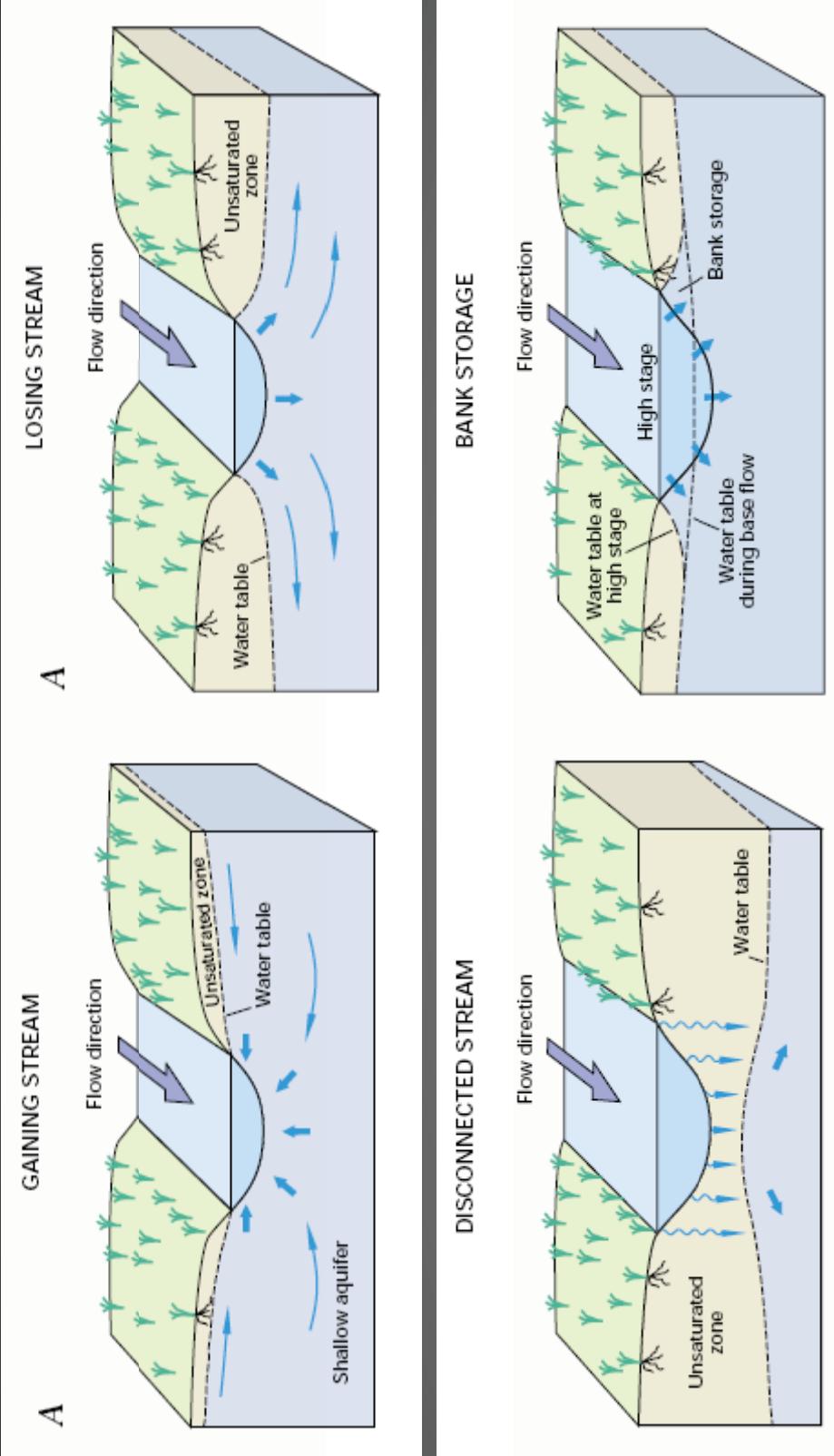
- Groundwater flow paths vary greatly in **length**, **depth** and **travel time**
- Groundwater pumped from wells can be **days** old to **thousands of years** old



# Unconfined vs. Confined Aquifers

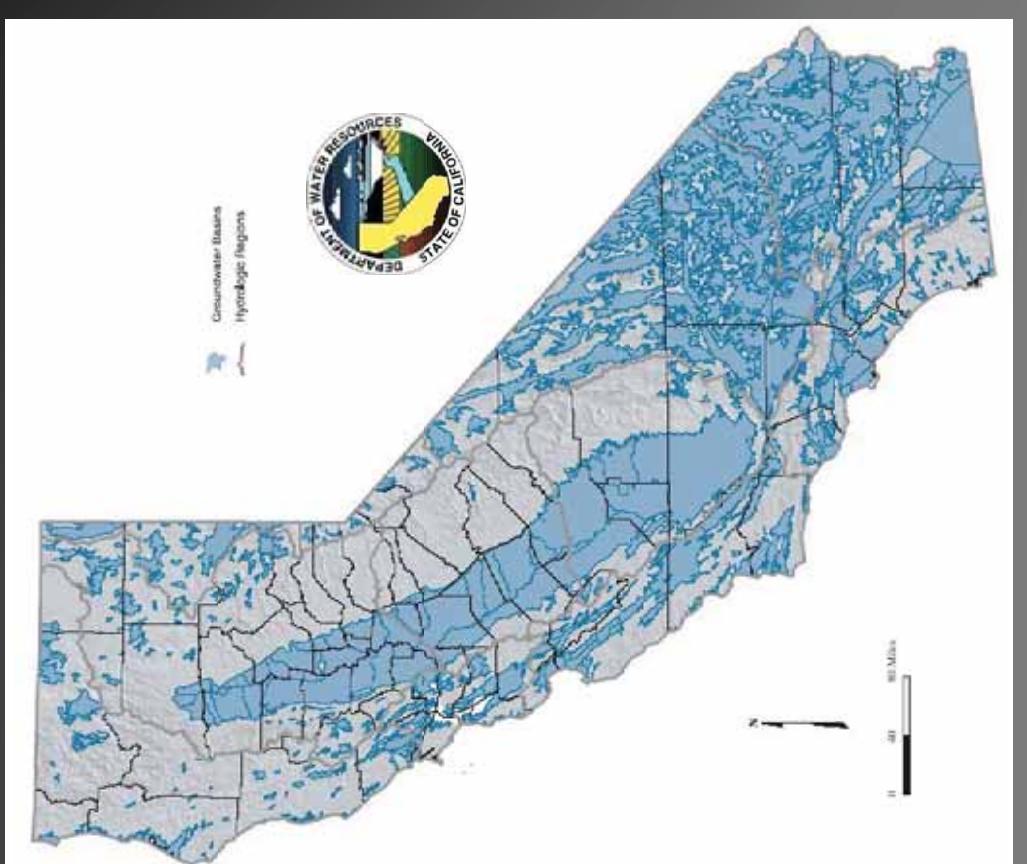


# Groundwater Interactions with Streams

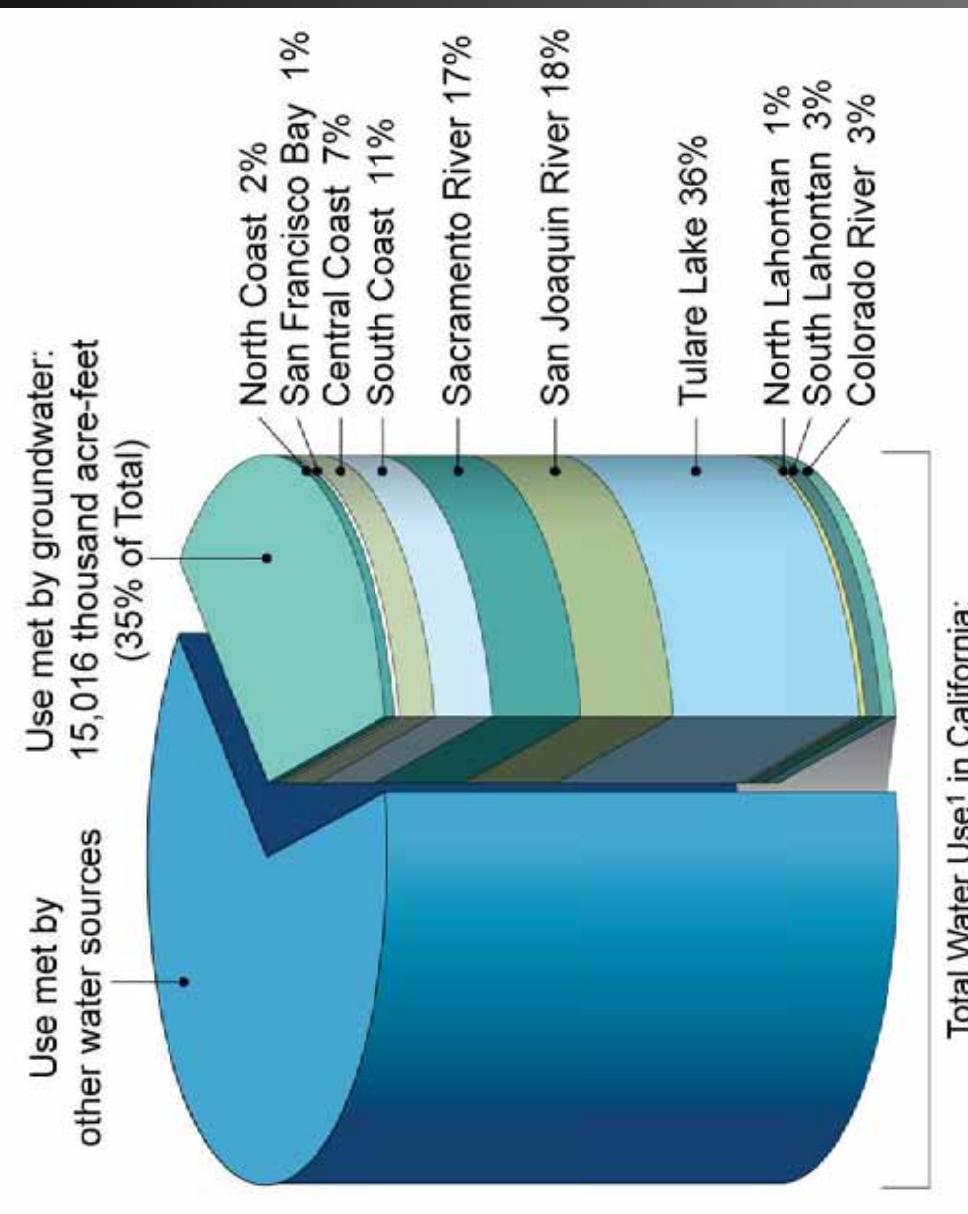


# California's Groundwater

- Groundwater basins are identified in Bulletin 118 – Update 2003
  - 515 alluvial basins and subbasins delineated



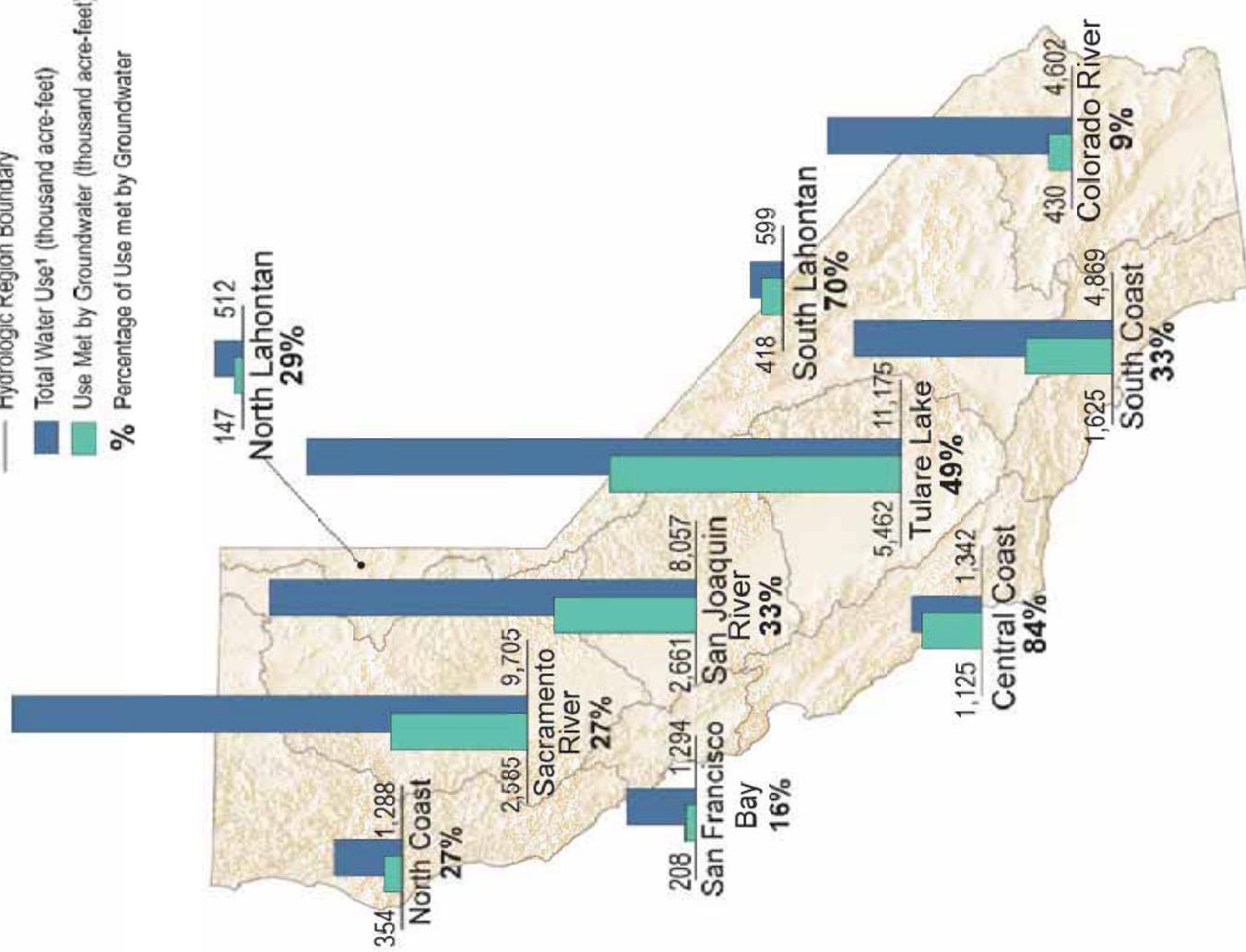
## Water Use Met by Groundwater in California: Statewide and by Hydrologic Region (1998-2005 average annual data)



1. Total Water Use is defined as the sum of water uses for agricultural, urban, and managed wetlands.

## Groundwater use by Hydrologic Region (1998-2005 average annual data)

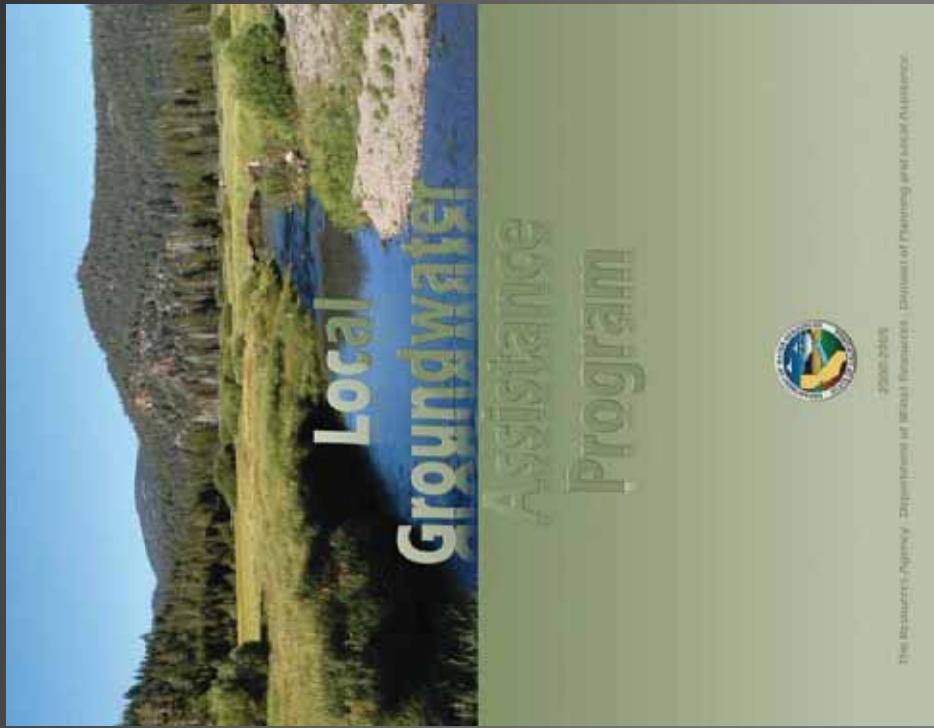
- 15 million acre-feet pumped
- 30% on average, higher in dry years
- Some cities and coastal basins entirely dependent
- Many rural users entirely dependent



1. Total Water Use is defined as the sum of water uses for agricultural, urban, and managed wetlands.

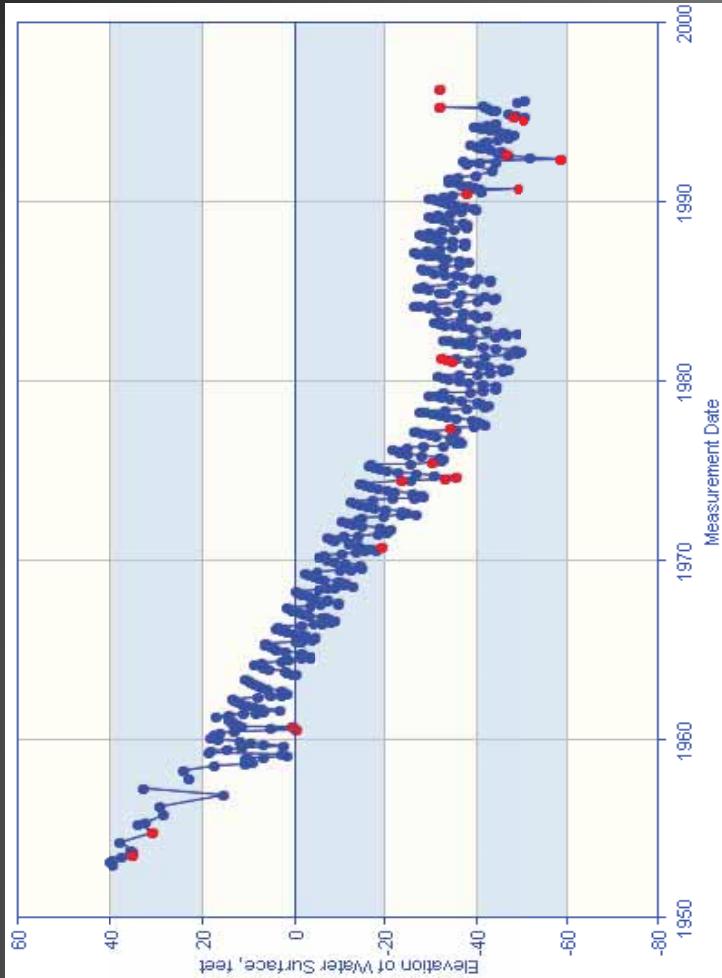
# Important Groundwater Management Legislation

- California Water Code Sections 10750 et seq.
- 1992: AB 3030 – Groundwater Management Plans (GWPMP)
- 2000: AB 303 – Local Groundwater Assistance grants
- 2002: SB 1938 – Required elements in GWPMPs to be eligible for grant funds
- 2009: SBx7 6 (CASGEM) – Statewide seasonal and long-term groundwater elevation monitoring

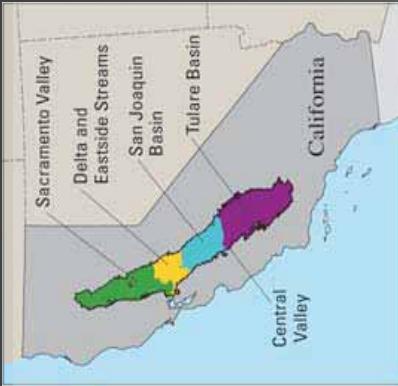


# Groundwater Overdraft

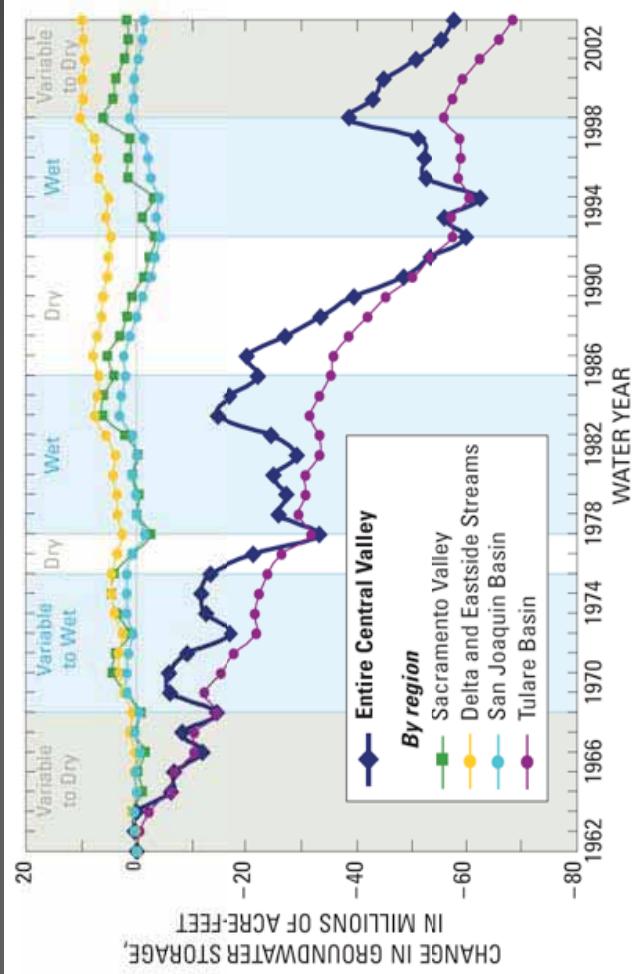
- The amount of water pumped exceeds the amount of water recharged over a period of years
- Bulletin 118-2003 estimates a statewide average groundwater overdraft of 1-2 MAF per year
- Primarily in three hydrologic regions:
  - Tulare Lake
  - San Joaquin River
  - Central Coast



# Central Valley Hydrologic Model



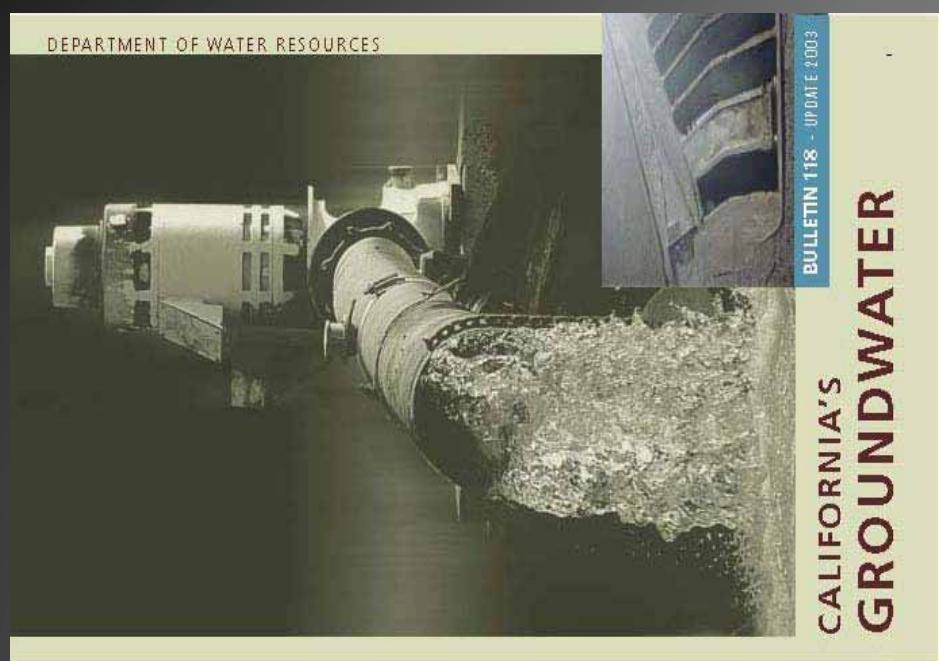
Faunt, C.C. ed., 2009



- Published by USGS in 2009
- Study period 1962 to 2002
- Simulated loss of GW storage of 57.7 MAF over study period
  - This equates to an average GW overdraft of ~1.4 MAF per year
  - This is comparable with DWR's estimate of 1-2 MAF per year
  - Overdraft is primarily from the Tulare Basin

# SBX7 6 Legislative Intent

- Enacted in November 2009
- Local groundwater Monitoring Entities *regularly and systematically* monitor groundwater elevations in California's alluvial basins and subbasins
- Groundwater elevation information be made readily and widely available
- DWR continues to maintain its current network of monitoring wells and continues to coordinate monitoring with local entities

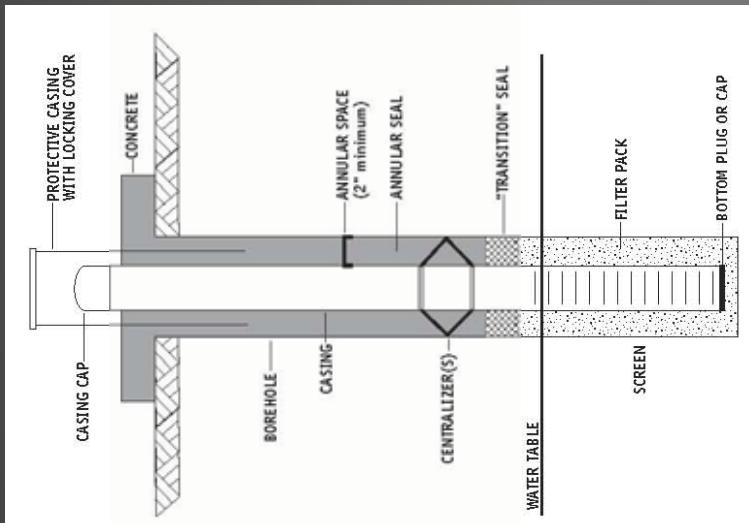


# What is CASGEM?

## California Statewide Groundwater Elevation Monitoring

- A statewide program to measure groundwater elevations in California's basins and subbasins
- Establishes collaboration between local Monitoring Entities and DWR to collect groundwater elevations
- Groundwater elevation data are a fundamental component necessary to successfully monitor and manage California's limited groundwater resources

# How is groundwater elevation data collected?



# What is CASGEM? (cont.)

- Groundwater Monitoring Entities are voluntary
- Local agencies measure groundwater elevations in their basin
- Groundwater Monitoring Entities will coordinate the collection of groundwater elevation data from their wells and will submit data to DWR
- All groundwater elevation data and selected well information will be made available to the public through the CASGEM website

# What is CASGEM? (cont.)

- DWR will report its findings to the Governor and the Legislature by January 1, 2012 and thereafter in years ending in 5 or 0
- DWR is not a monitoring entity as defined by the CASGEM Program
- If DWR assumes the monitoring role in a basin due to lack of local support, certain entities in the basin may be ineligible for water grants or loans awarded or administered by the State

<http://www.water.ca.gov/groundwater/casgem>

**Summer  
2010**

## **ACWA/DWR Workshops**

- Draft Guidelines
- Solicit Comments
- Finalize Guidelines

**Fall 2010**

**Develop online notification  
and data submittal system**

**Local agencies work  
together to identify  
prospective  
Monitoring Entities**

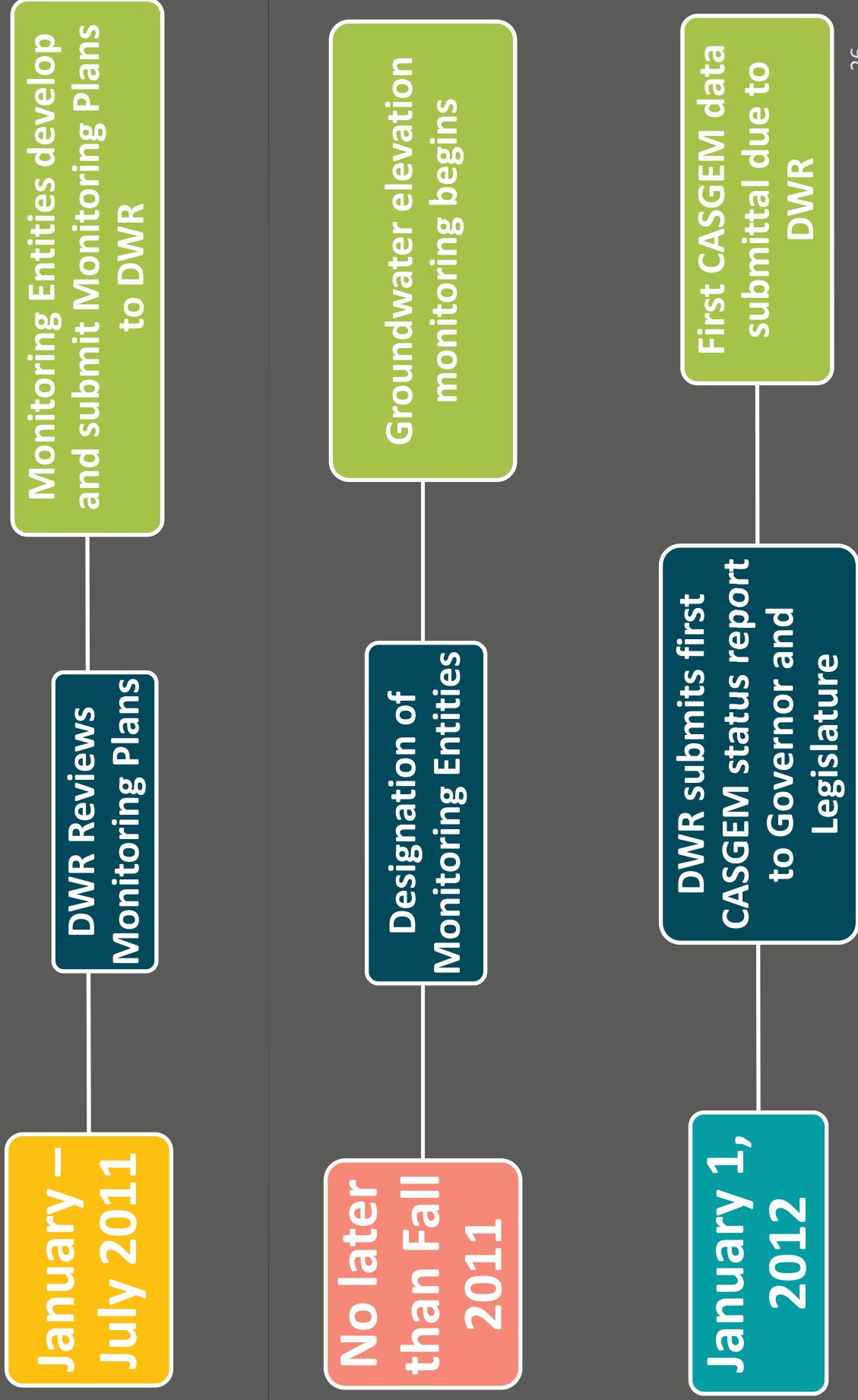
**Late Fall 2010**

**Online  
notification  
system ready**

**Prospective Monitoring  
Entities begin submitting  
notifications to DWR**

**January 1, 2011**

**Monitoring Entity  
notifications due to DWR**



# CASGEN Goals

## SHORT TERM

- Encourage local participation throughout the state
- Determine the extent of groundwater elevation monitoring in California's groundwater basins
- Provide assistance to local agencies

## LONG TERM

- Establish a statewide groundwater monitoring network that shows seasonal and long-term trends which will help to improve statewide water planning
- DWR Region Offices work with local agencies to better characterize California's groundwater basins

# CASGEM Challenges

- Tight deadlines
- Statewide program
- Limited resources, no funding with SBx7 6
- Diversity throughout the state
  - 515 basins with varied hydrogeology
  - Many agencies and diverse local interests
  - Various resource uses, needs, and constraints
  - Local agency participation is voluntary

# Questions



# Land Subsidence Accompanying the Development of Groundwater Resources, Central Valley, CA

Implications for State and Federal Aqueducts

Michelle Sneed  
California Water Science Center  
U.S. Geological Survey  
January 28, 2011

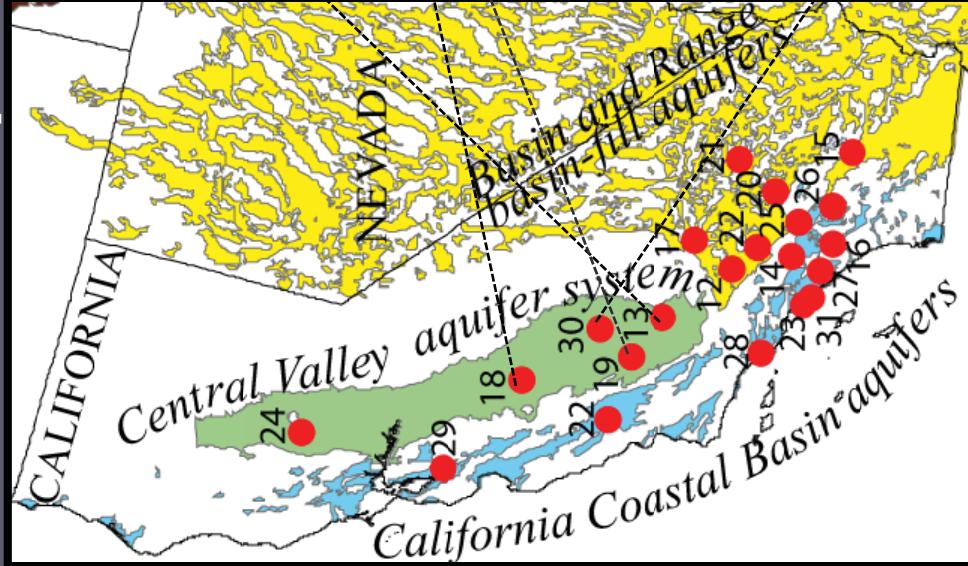


# Aquifer-System Compaction and Land Subsidence

- ▶ Where in California is it happening?
- ▶ How long has it been happening?
- ▶ What causes it and how is it different than subsidence in the delta?
- ▶ How is subsidence monitored?
- ▶ Why should we care about subsidence in the Central Valley?
- ▶ What is the future of subsidence?



# Scope: California Central Valley



ID	Location Name	Fluid
12	Antelope Valley	W
13	Arvin-Bakersfield-Manicopa area (San Joaquin Valley)	W, O&G
14	Chino Basin (and adjacent Claremont and Pomona basins)	W
15	Coachella Valley	W
16	Elsinore Trough (Elsinore, Temecula and Wolf valleys)	W
17	Fremont Valley	W
18	Los Banos-Kettleman City area (San Joaquin Valley)	W
19	Lost Hills-Belridge (San Joaquin Valley)	O&G
20	Lucerne Valley	W
21	Mojave River Basin	W
22	Paso Robles	W
23	Redondo Beach	O&G
24	Sacramento Valley	W
25	San Bernardino	W
26	San Jacinto Basin	W
27	Santa Ana Basin	W
28	Santa Clara-Calleguas Basin (Oxnard Plain)	W, O&G
29	Santa Clara Valley	W
30	Tulare-Wasco area (San Joaquin Valley)	W
31	Wilmington	O&G

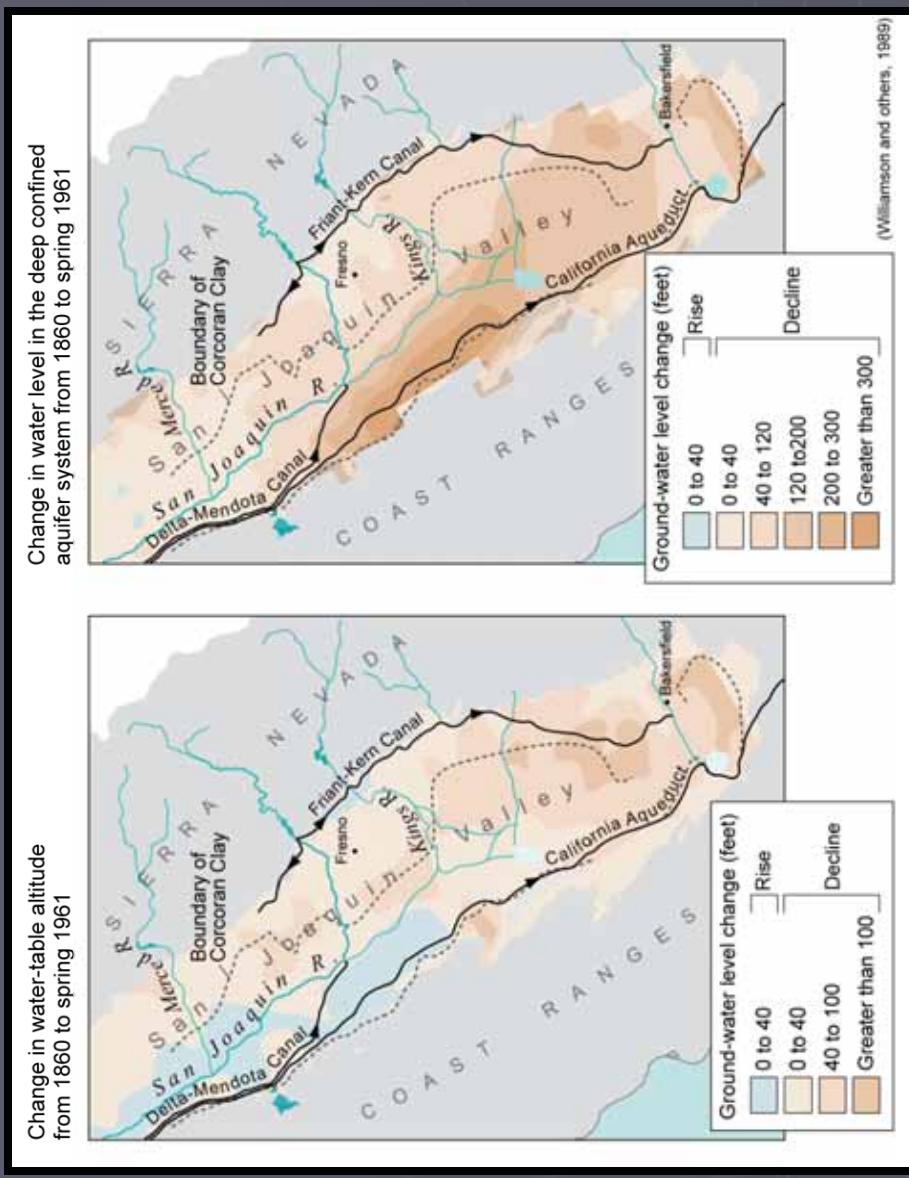
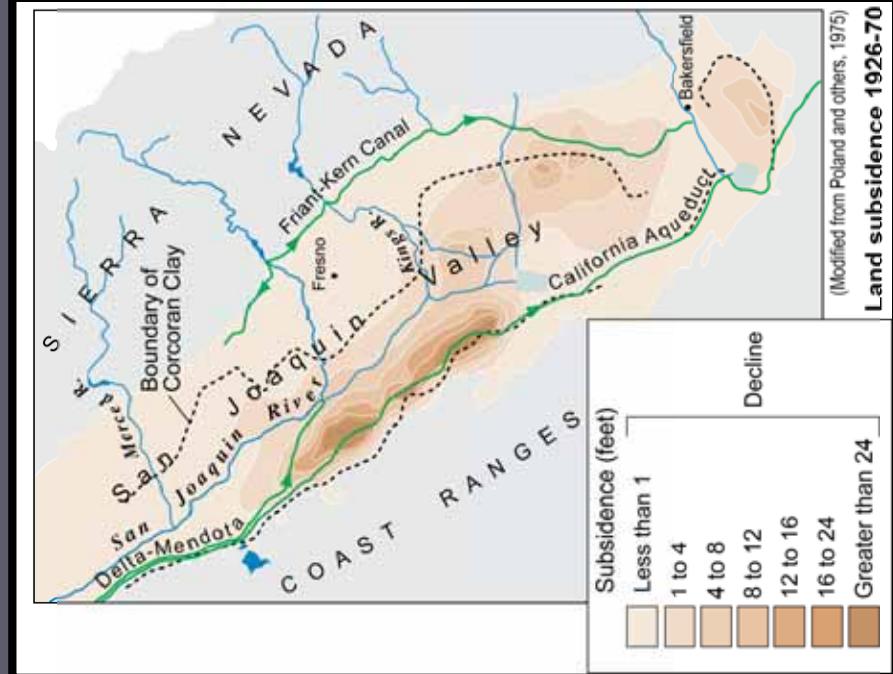
## Reported subsidence caused by groundwater withdrawal

Maximum Areas Affected: San Joaquin, Antelope and Santa Clara Valleys

Maximum Magnitude: San Joaquin, Santa Clara and Antelope Valleys



# Scope: San Joaquin Valley, CA



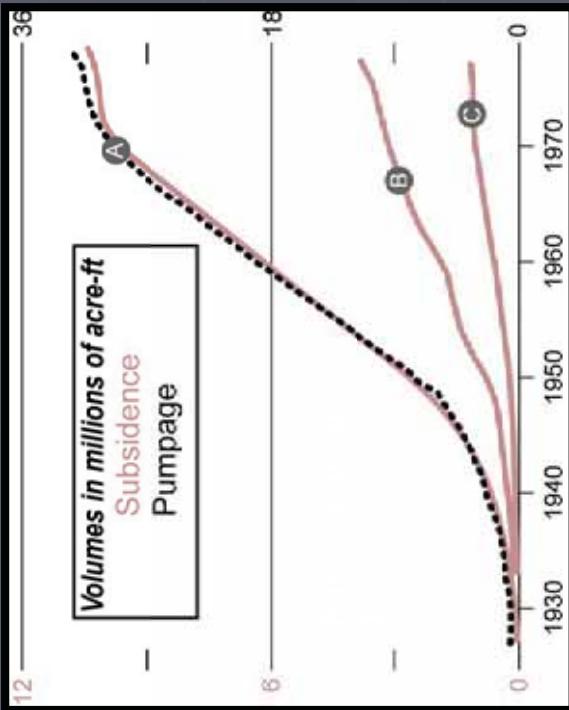
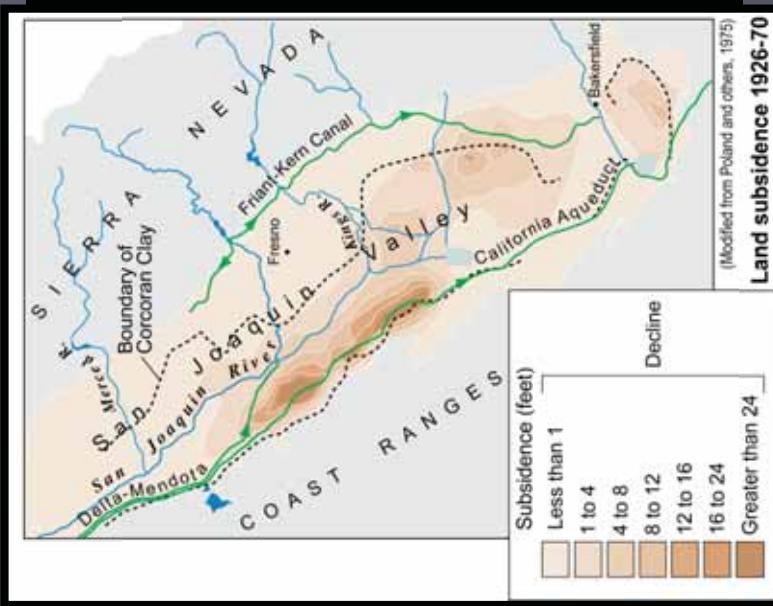
## Extensive withdrawal of groundwater caused widespread subsidence

- Subsidence began in the mid-1920's
- By 1970, area affected: ~5,200 mi<sup>2</sup> with > 1 ft of subsidence

## Reported subsidence caused by groundwater withdrawal

Maximum Volume: Los Banos-Kettleman City area (A)

Maximum Magnitude: Los Banos-Kettleman City area (A)

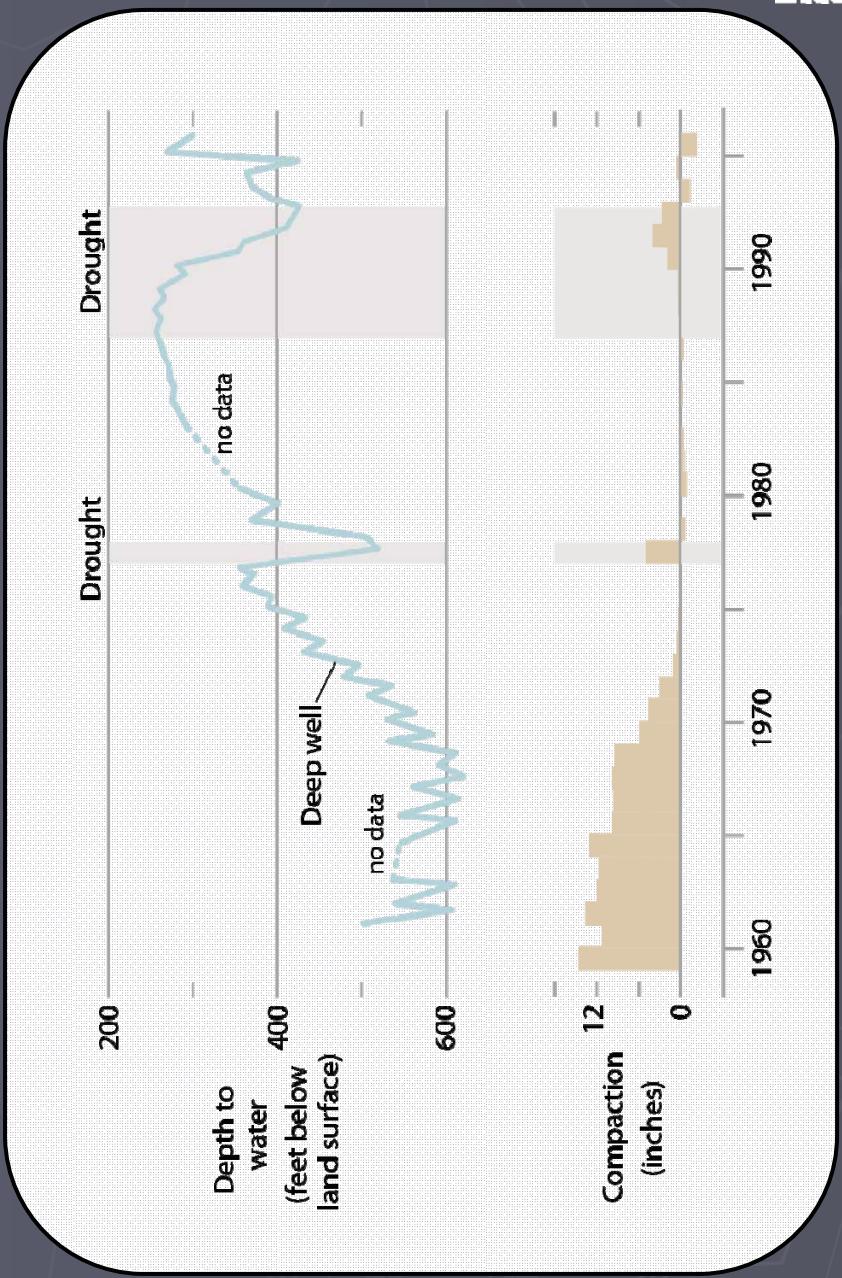


Notice that the California Aqueduct and Delta-Mendota Canal traverse subsidizing areas

Importation of surface water in the early 1970s resulted in steady recovery of water levels and reduced rates of subsidence

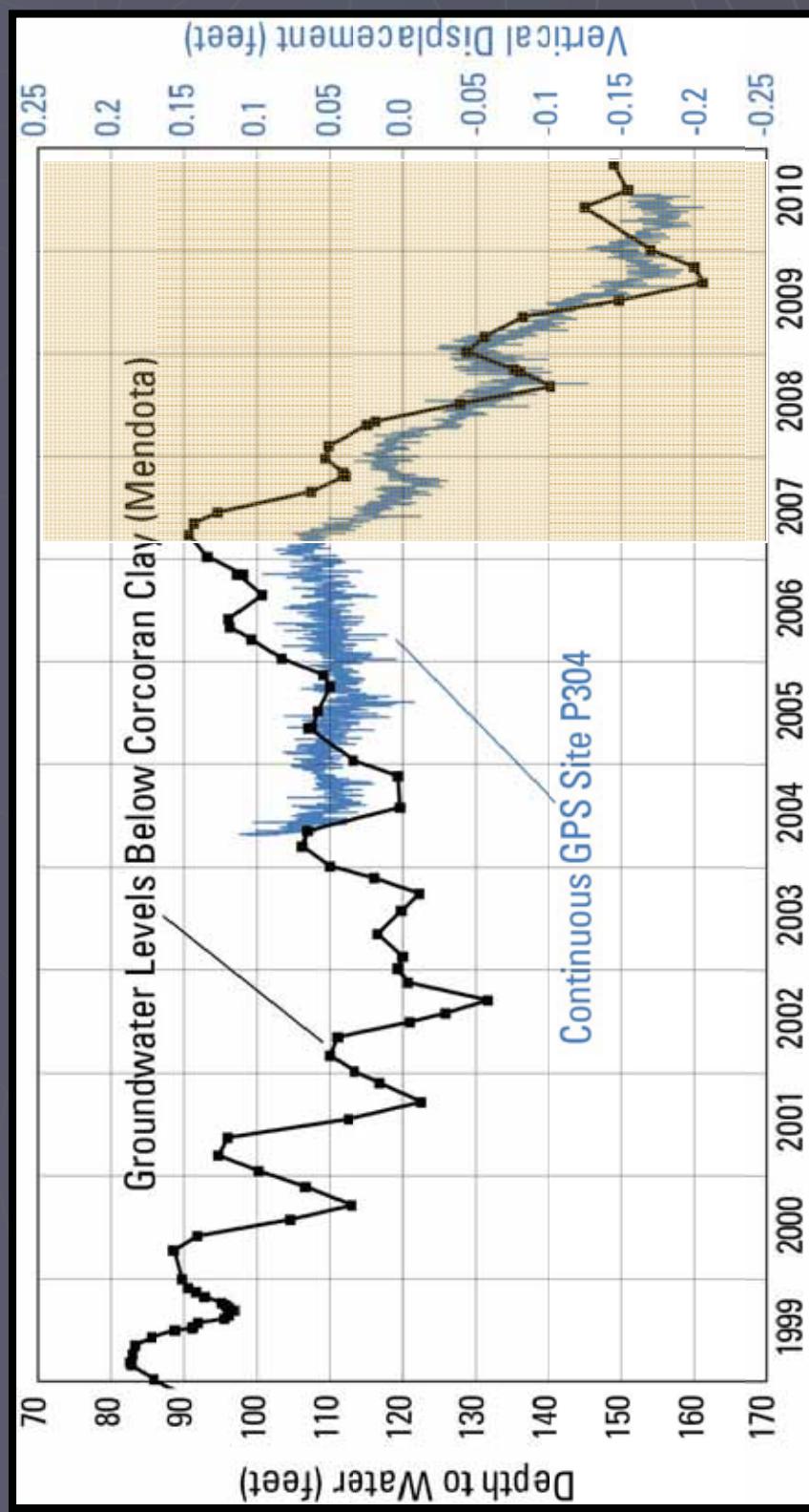
# Droughts and Subsidence

- Droughts of 1976-77 and 1986-91
  - Diminished deliveries of imported water prompted increased groundwater pumping
  - Periods of renewed subsidence



# Recent Subsidence

- Recently: renewed subsidence concern
  - Reduced surface water importation
  - More reliance on the groundwater resources



P304 data from UNAVCO; water-level data from Luhdorff and Scalmanini Consulting Engineers



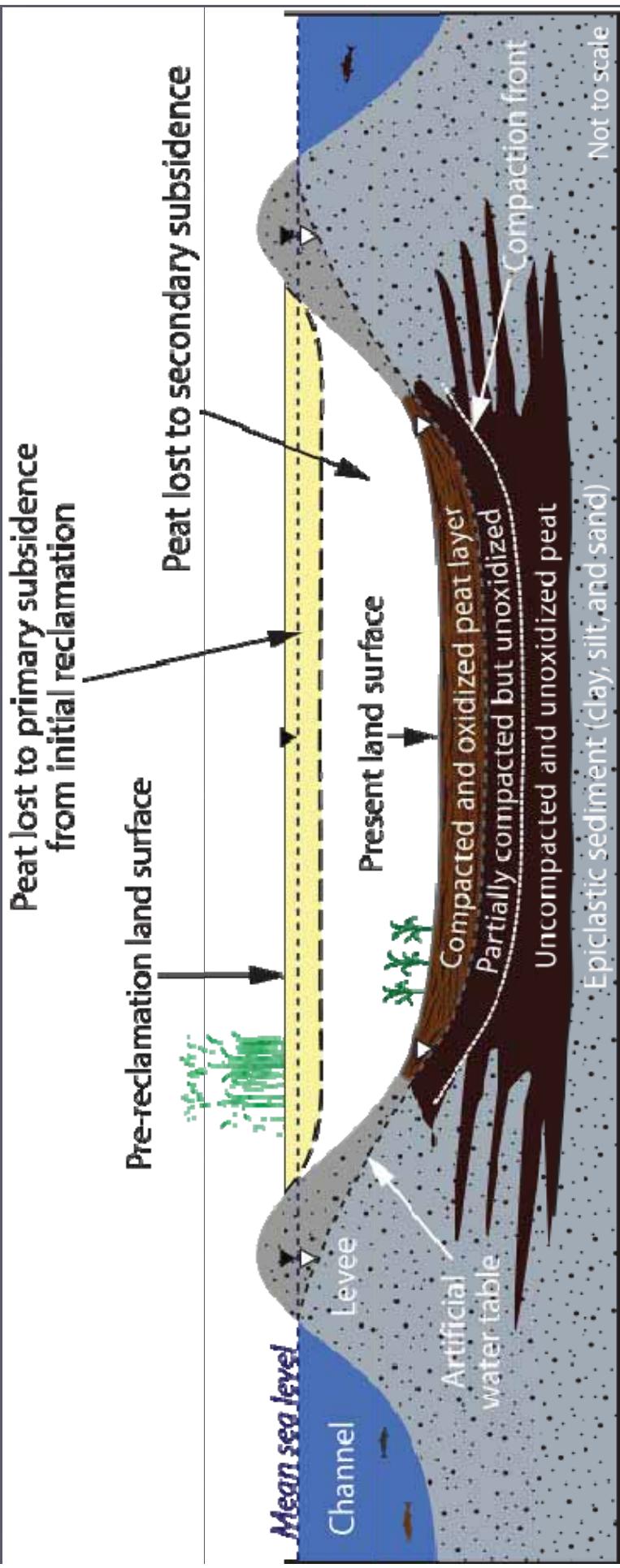
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- ▶ How is subsidence monitored?
- ▶ What is the future of subsidence?



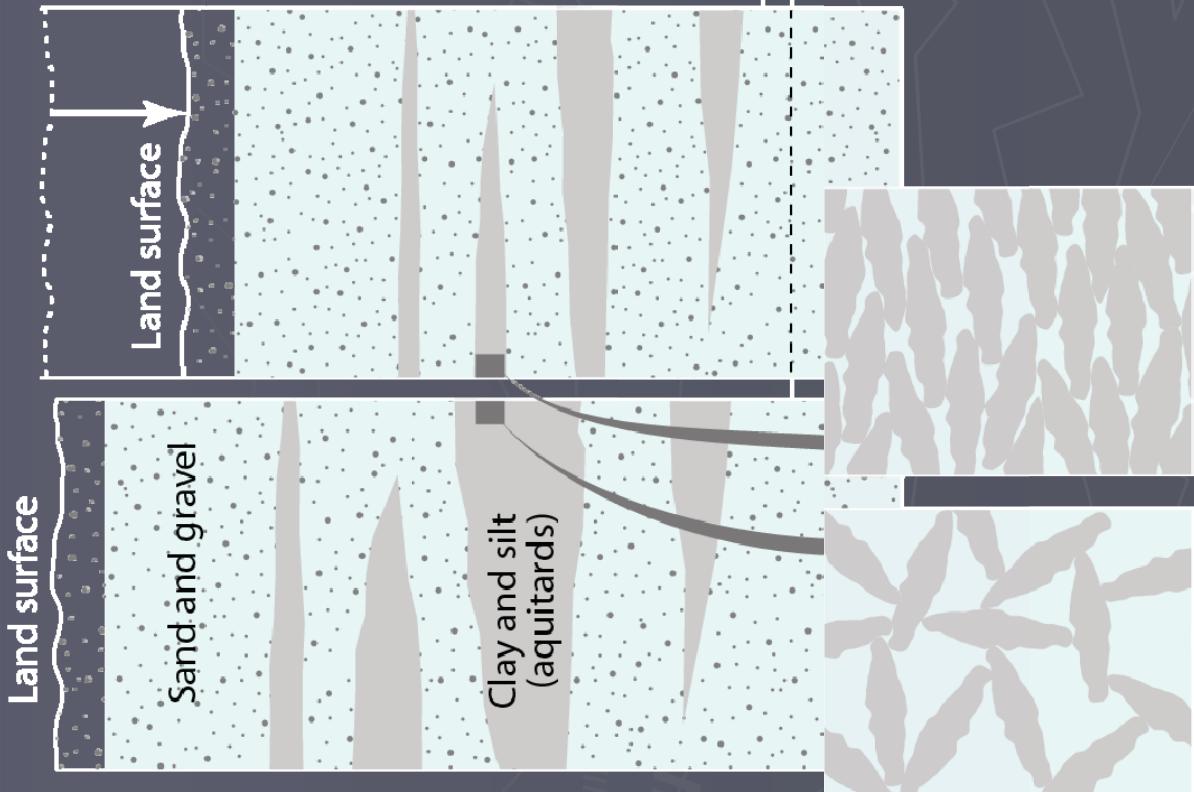
# Land Subsidence in the Delta

## A surficial process

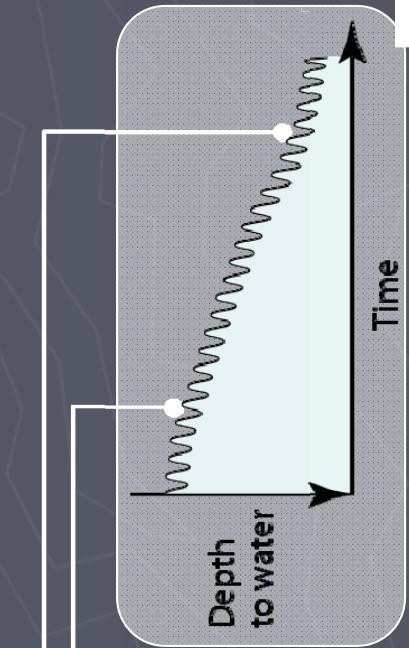


# Land Subsidence in the San Joaquin Valley

## A deep process: Aquifer-System Compaction



- Concentrated in the aquitards
- Inelastic (irreversible ) compaction occurs when the preconsolidation stress is exceeded
- Preconsolidation stress ≈ previous lowest groundwater level
- Storage capacity is reduced



# Aquifer-System Compaction and Land Subsidence

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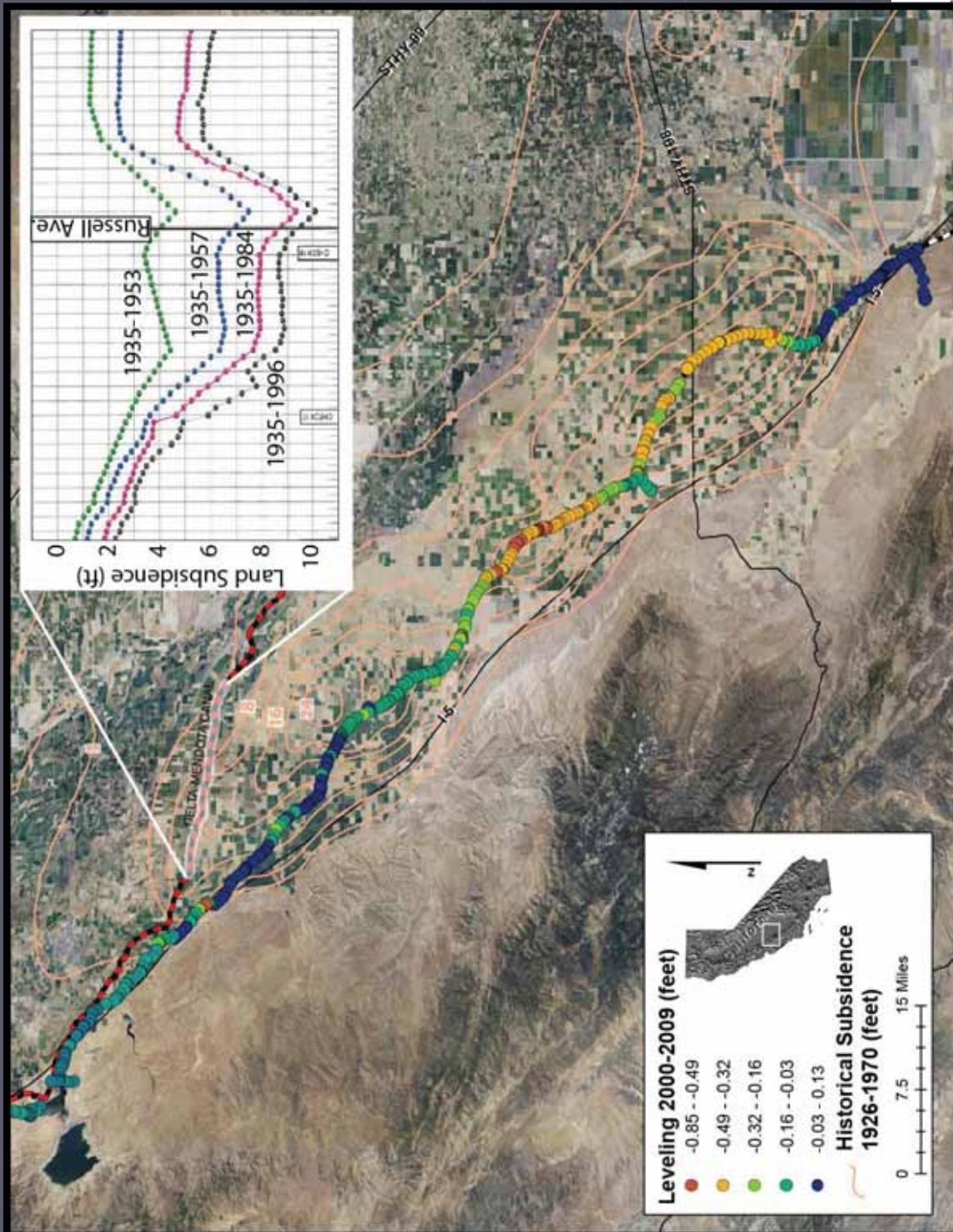


# Subsidence/Aquifer-System Deformation Measurement Methods

- Land Survey
  - Spirit leveling: usually along highways, railroads, and canals
  - Global Positioning System (GPS)
- Extensometer
- Interferometric Synthetic Aperture Radar (InSAR)
- Hydrogeologic framework (water levels, geology, etc.)

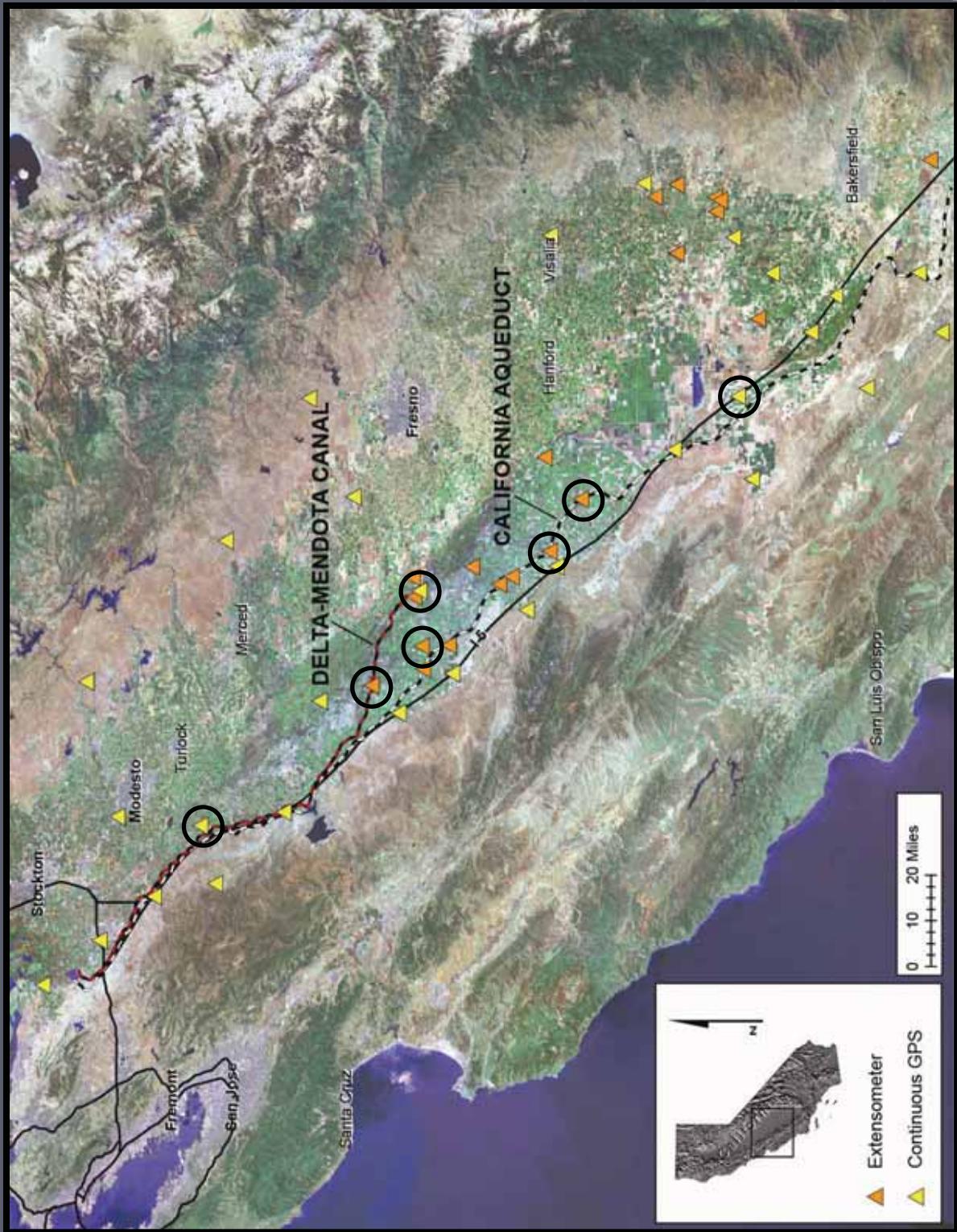


# Leveling Along Aqueducts

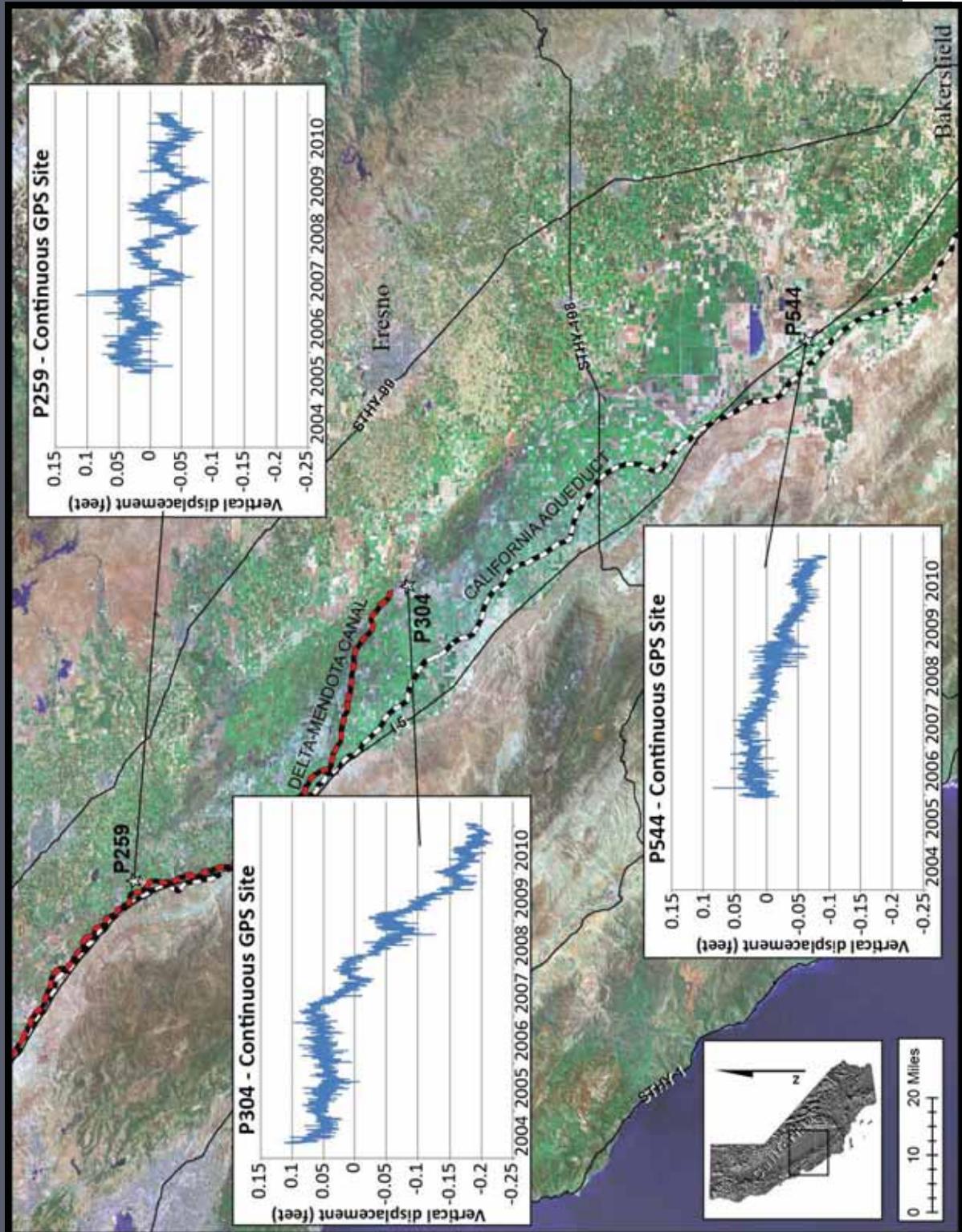


Aqueduct leveling data from DWR; DMC leveling data from SLDMWA

# Extensometers and Continuous GPS

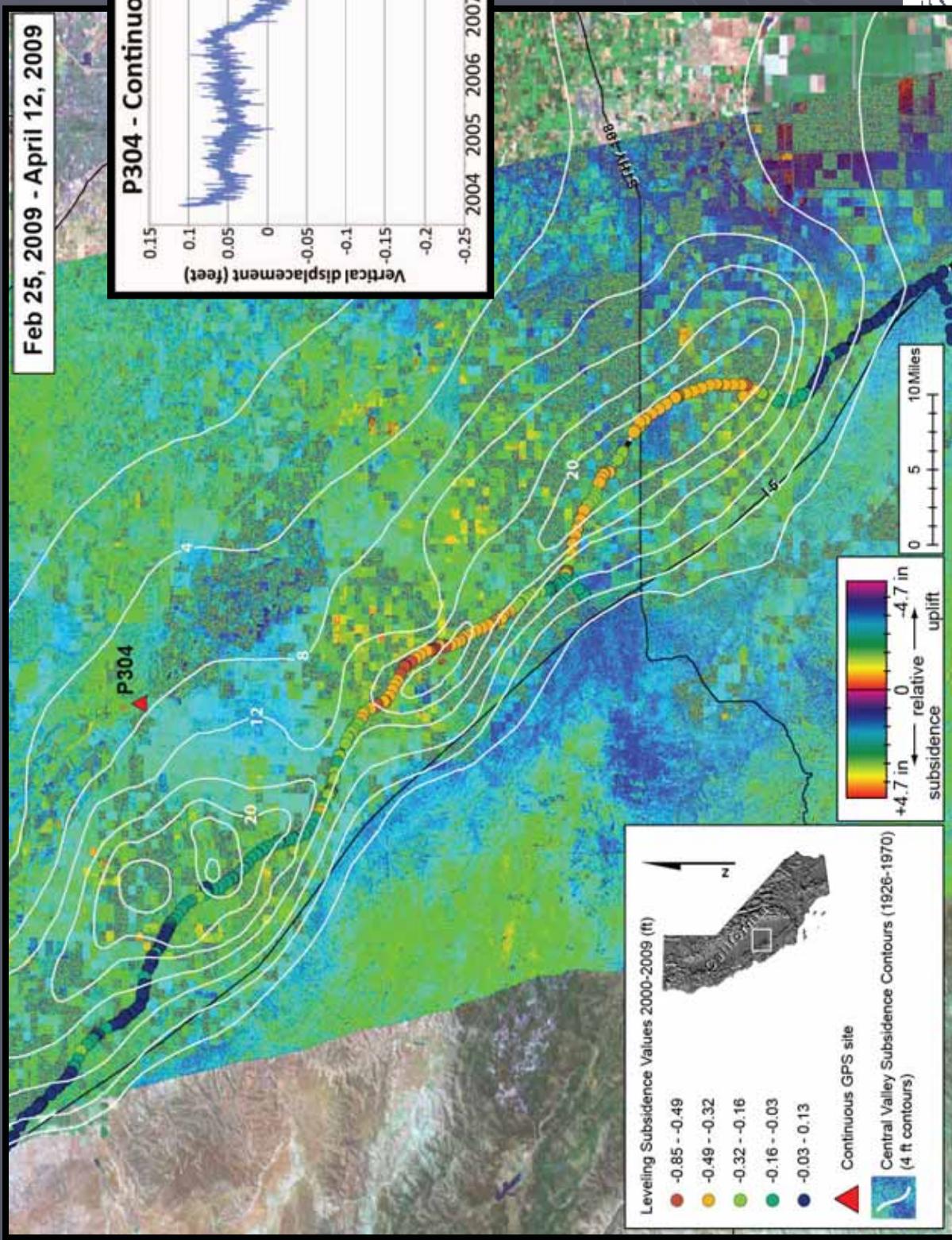


# Continuous GPS data Along Aqueducts



GPS data from UNAVCO

# InSAR



# Aquifer-System Compaction and Land Subsidence

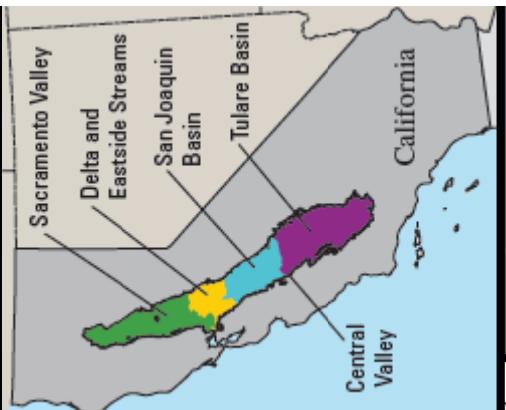
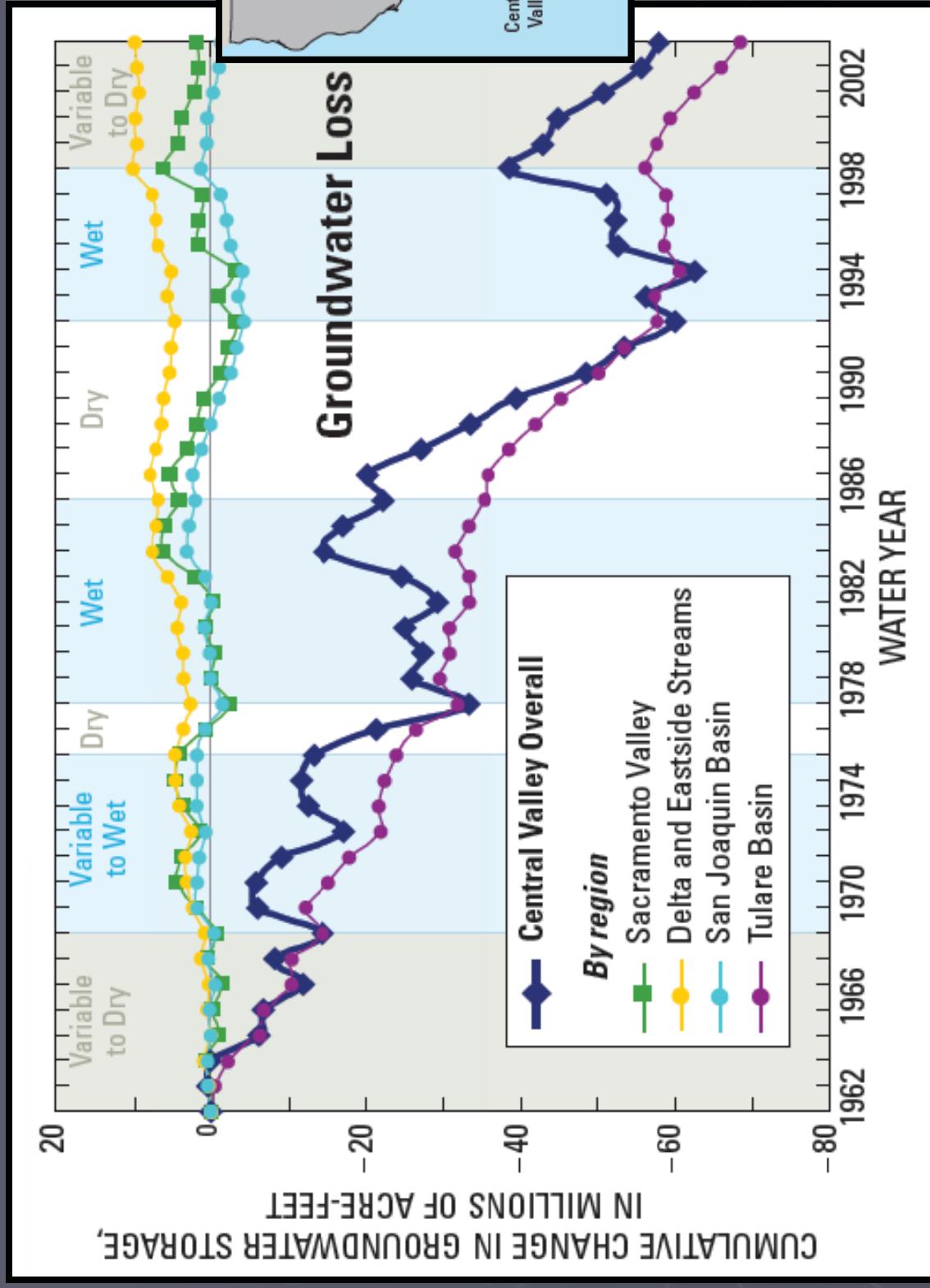
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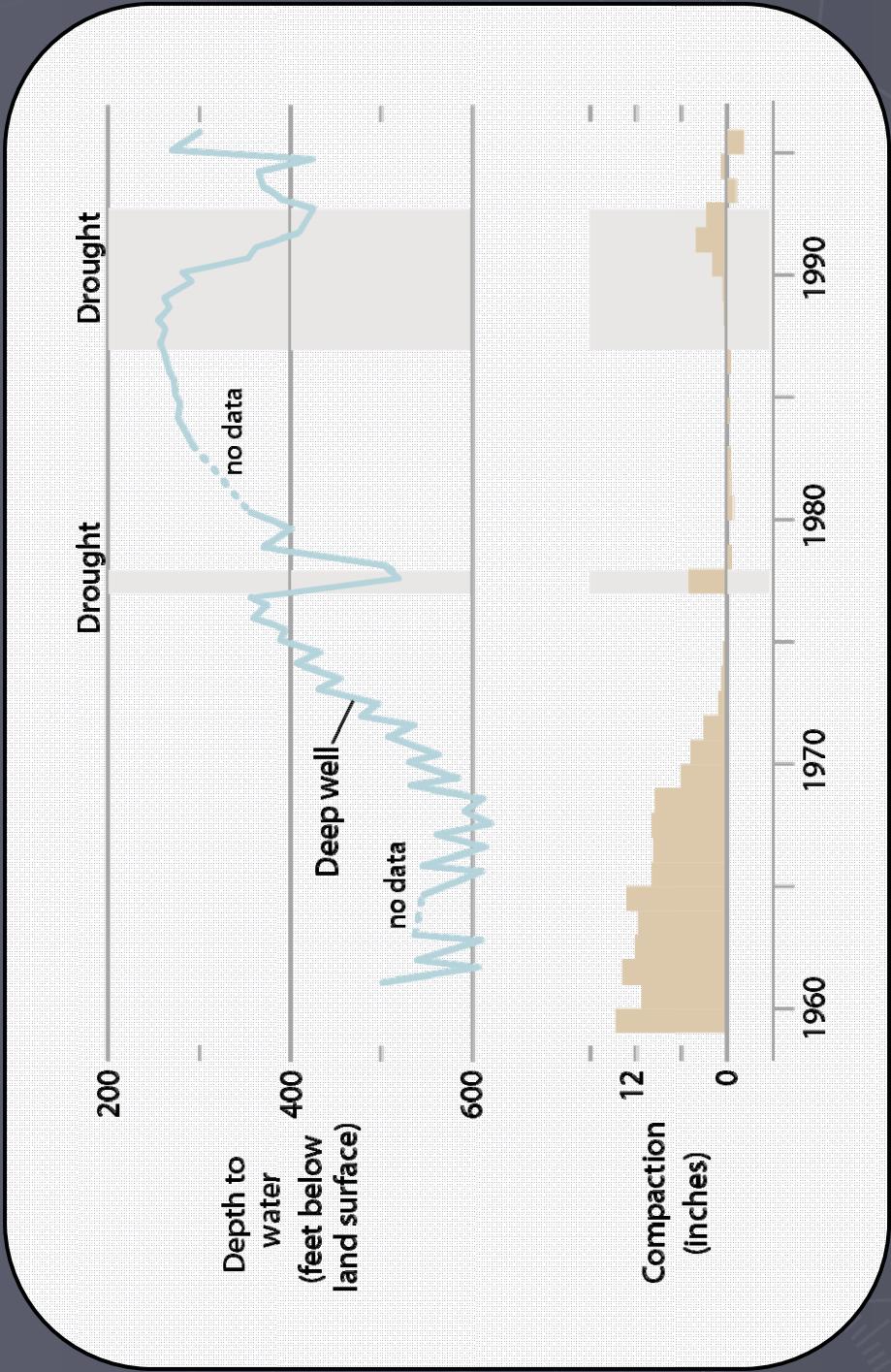
# Subsidence Damages Natural Resources and Infrastructure

- Natural resources
  - Reduces aquifer-system storage capacity
  - Impacts to wetland, riparian, and aquatic ecosystems
  - Restricted land uses
- Infrastructure
  - Damage to water conveyance systems and other infrastructure
  - Lost freeboard, panel damage, water surface and liner misalignment, reduced conveyance capacity
  - Roads, rails, bridges, pipelines, wells, etc.

# Change in Storage

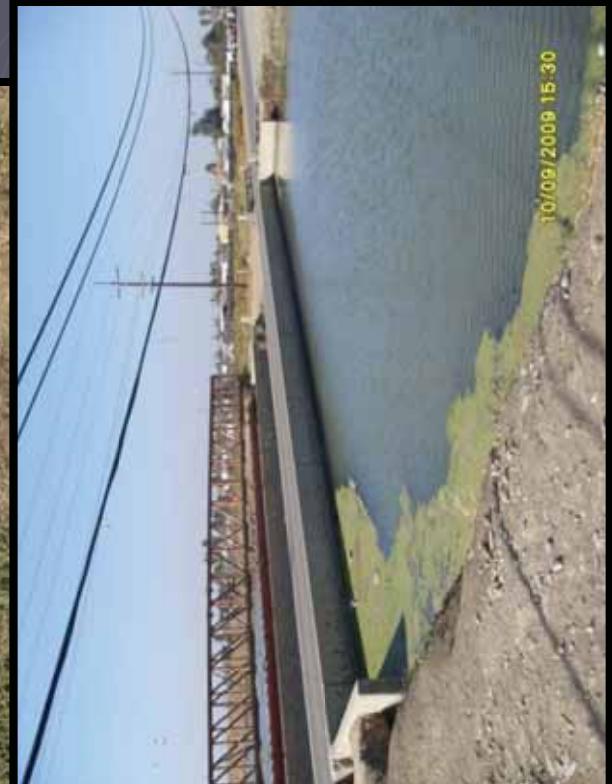
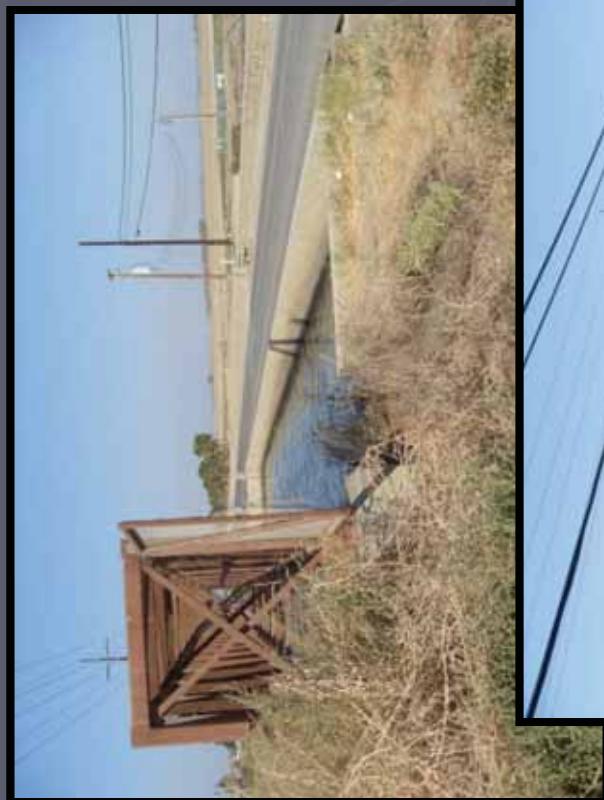


# Impact Of Lost Aquifer-System Storage Capacity



Groundwater levels decline more quickly than previously

# Impact On Infrastructure



Pictures courtesy of Chris White, Central California Irrigation District



# What is the Economic Impact?

- Vastly underestimated and under reported

Estimated Costs of Subsidence

Site	Damages	Costs <sup>1</sup> , M\$
Santa Clara V.	Levees, wells, sewers, roadways	375
San Joaquin V.	Canals; design modifications	145
Long Beach	Flood; structural	600

<sup>1</sup>Costs in year 2007 \$US

Sources: Fowler, 1981; Freeze, 2000; NRC, 1991



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# Past is the Key to the Future

- If groundwater levels are drawn down equivalent to or beyond historic lows, subsidence will re-initiate
- Conservatively, we could match historical rates.  
That's not to say those rates can't be exceeded
- Impacts of a climate change scenario



# Future Trend?

Simulated subsidence, in feet,

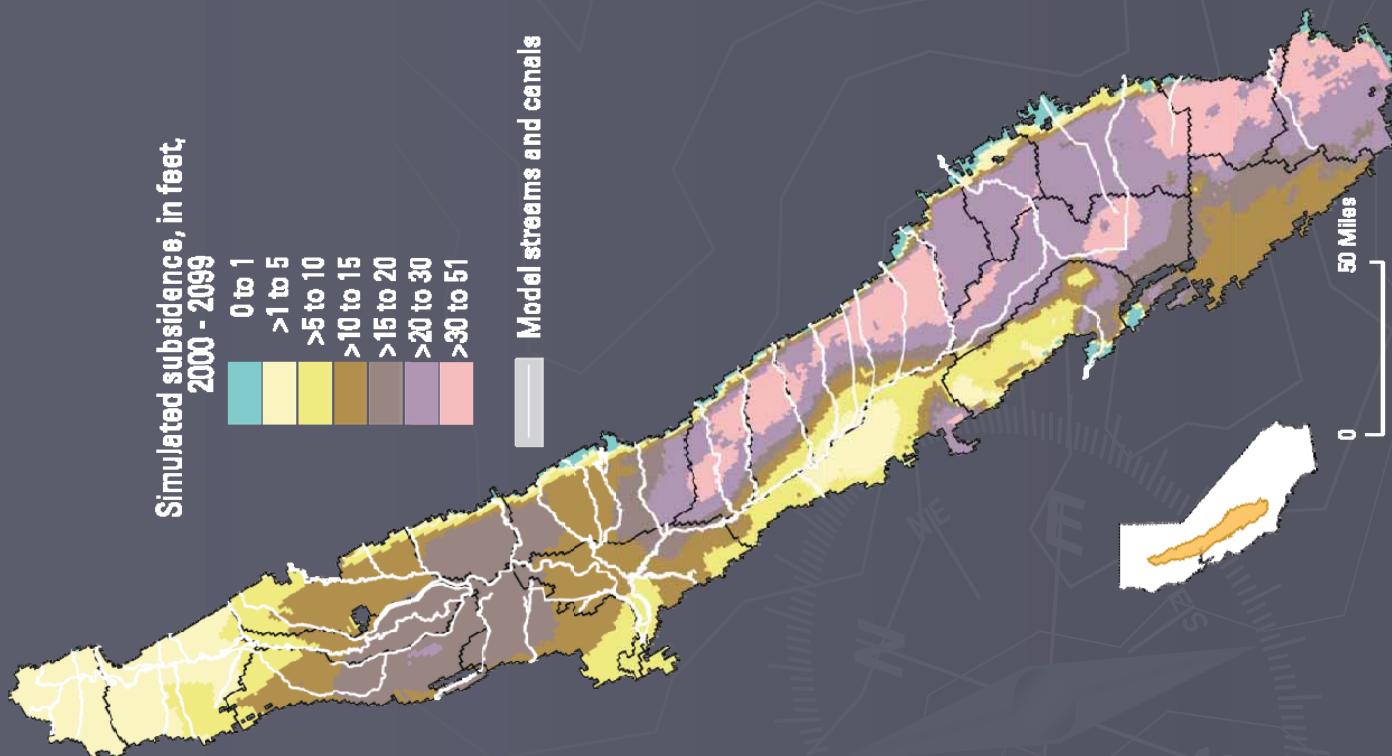
2000 - 2099



## Old and New Subsidence

- Renewed subsidence in historical areas
- Largest new subsidence
  - Adjacent to Sierras where surface-water deliveries for irrigation are less
- Additional subsidence in growing urban areas
- Nearly 200 million acre-ft from fine-grained sediments in 21<sup>st</sup> Century

Model streams and channels



Hanson and others, 2010



# What Can Be Done About It?

- ▶ Focus on maintaining groundwater levels above the critical threshold
  - Reduction of groundwater withdrawal
    - ▶ Decreasing groundwater demand
    - ▶ Limiting/redistributing groundwater use
    - ▶ Increasing supplemental water supply
  - Enhanced groundwater recharge
    - ▶ Artificial recharge: direct well injection or surface infiltration
    - ▶ Natural recharge: source protection

